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ON SOME AMERICAN AND ORIENTAL EARTHWORMS

PART II. FAMILY MEGASCOLECIDAE

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Part I of this article contains descriptions and notes on distributions of earthworms of the families *Moniligastridae, Glossoscolecidae* and *Lumbricidae,* sent recently to the Zoology Department of The Ohio State University for identification. Included among this material is the first specimen of the large Indian earthworm, *Drawida grandis* (Bourne) 1886, that has been available for study since the species was first described.

Part II contains descriptions and notes on similar material belonging to the family *Megascolecidae.*

Family MEGASCOLECIDAE

Genus PONTODRILUS E. Perrier, 1874

Pontodrilus bermudensis Beddard 1891

Material examined.—Under sea weed on beach, St. Croix, Virgin Islands, March, 1938, 5 aclitellate specimens. H. A. Beatty per U. S. Nat. Mus.

External characteristics.—Length to 55 mm. Diameter to 2 mm. Prostomium slightly epilobous. Setae: posterior to xx *aa, bc* and *cd* are about equal or *bc* may be smaller than *cd, ab*<*cd, dd*<½C. Nephropores are not certainly recognizable but appear to be on *c*. No dorsal pores.

Spermathecal pores are minute, on 7/8 and 8/9, on or just lateral to *b*. Female pores are on xiv anteromedian to *a* and slightly nearer to 13/14 than the setal arc. Male pores are minute, on xviii, on the setal arc and about on *b*. A grey spot on the setal arc of xviii on *a* appears to mark former site of an aperture into a setal follicle.

Segment xviii is anteroposteriorly elongated ventrally and especially so in a region extending from just median to *a* nearly to *c* on each side. Approximately in *ab* on each side of xviii is a longitudinally placed area of greyish translucence, rather sharply demarcated but with sinuous margins. Each area is indented mesially and laterally by a white, rather conical, undemarcated protuberance, the lateral especially conspicuous, the protuberances reaching highest elevation on the setal arc.

The single genital marking (5) is on 19/20, reaching laterally on each side about half way to *a*, with central translucent and marginal opaque portions demarcated on the larger specimens.

Internal anatomy.—There is a rudimentary gizzard in v (3, not noted in other two specimens). Calciferous glands and lamellae are lacking but the oesophageal wall is thickest and

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most vascularized in xiv–xv. The intestine begins anteriorly in xvii (3), the oesophageal valve in the region of attachment of septum 16/17. No typhlosole.

The dorsal blood vessel (single) is continued anteriorly onto the pharyngeal bulb. A supra-oesophageal trunk is unrecognizable. Extra-oesophageals are large, close to the ventral parietes in i–v, much more dorsal posteriorly, passing onto the gut in xii–xiii, uniting mesially in xiv or xv. No subneural trunk (3). Last hearts in xiii (5).

Nephridia of xiii are small (5), no nephridia in xiv or anteriorly, larger nephridia present from xv posteriorly (5). The preseptal funnels are close to the ventral parietes in *ab*.

Holandric, acinous seminal vesicles present in xi and xii (5). The prostatic duct is curved into a sigmoid or C-shape, one to two mm. long and nearly as long as the gland, with marked muscular sheen. On the median faces of the prostatic ducts within the parietes are very small setal follicles. The vasa deferentia were not traced as they are not certainly recognizable posterior to xi.

The spermathecal duct is about as long as or longer than the ampulla from which it is fairly sharply marked off, adherent (by the posterior face) to or imbedded in the parietes back to the level of the setal arcs of viii and ix. The digitiform diverticulum passes to the median face of the duct within the parietes and is long enough to reach up slightly onto the ampulla.

The epidermis of the genital marking on 19/20 is markedly thickened. White material within the body wall under each protuberance on xviii may be glandular.

Remarks.—The intestine of each specimen is largely filled with coral fragments including some that are as much as 1½ mm. long. Also included is a disc of approximately circular outline and with a diameter of one mm. Bits of coral of appropriate size and disposition in the oesophagus may produce an appearance of the presence of gizzards or of calciferous glands. A bit of yellowish, calcareous tube of approximately segmental length and completely filling the gut in vii produced an appearance practically indistinguishable from that of a gizzard until the gut was opened. The oesophagus in v is widened, the shape approximating to that of a gizzard and the wall is definitely thicker than in iv or vi.

In the spermathecal ampullae of the larger specimens there is brownish material which may indicate that such individuals are in a postsexual stage after completion of clitellar regression.

The worms described above appear to be referable to *P. bermudensis* as now understood but the species is variable and Michaelsen (1909) recognized a number of *formae*, the taxonomic status of some of which must be regarded as doubtful.

Pontodrilus gracilis sp. nov.

Material examined.—Edge of Caloosahatchie River (brackish), Fort Myers, Florida, January 23, 1941, 21 aclitellate specimens. Prof. W. M. Barrows. Caloosahatchie River, Fort Myers, Florida, February 19, 1941, 15 aclitellate specimens. Prof. W. M. Barrows.

External characteristics.—Length to 170 mm. Diameter to 2½ mm. Unpigmented. Prostomium epilobous, *ca.* ½, but with no transverse furrow at posterior end of tongue (20). No dorsal pores. Nephropores are on *b*, presetal, about one quarter of the distance from intersegmental furrows towards the setal arcs, the pores of xviii, often slightly enlarged, just lateral to the genital markings. Setae begin on ii but may be lacking in part on ii–vi, near the hind end the dorsal ranks quite irregular, the lateral setae fairly closely or widely paired or widely separated; on xx, *cd* slightly larger than 2*ab*, *bc*, *cd*, and *aa* about equal, *dd*>2*cd*.

Quadrithecal, spermathecal pores minute and superficial, each pore at center of a small, almost circular protuberance, in *ab* and usually on or near mid *ab* (never on *a* or *b*), the intersegmental furrows lacking on the porophores. Female pores are on xiv, median to *a*, about halfway between 13/14 and the setal arc.

Male pores are minute and superficial, on xviii, on or close to sites of *b* setae, the apertures larger than those of setal follicles or of the female ducts but so recognizable only after removal of cuticle, each pore on a small, rounded or conical protuberance which may be surrounded by a marginal band of greyish translucence. On the most mature worms the porophores are

located in the lateralmost portions of a deep, transversely placed depression. Seta *a* of xviii is present on one side or the other of six specimens, on both sides of one specimen, otherwise ventral setae are unrecognizable.

Genital markings are one pair of presetal areas in *ab* on xviii (36). In the less mature specimens the markings are circular, sharply demarcated and each is surrounded by a marginal band of greyish translucence which is continuous with that around the male porophore. On more mature worms markings are elliptical in outline and longitudinally placed, 17/18 unrecognizable ventrally and some slight invasion of xvii possible. On three worms a slightly protuberant genital shield without definite demarcation extends from the setal arc of xvii at least to 18/19 and laterally to *c*. On these specimens as well as several others xviii is elongated ventrally and markedly widened. The genital markings indicate areas of marked parietal modification. Unpaired, median or other genital markings are lacking.

Internal anatomy.—Septa are present from 4/5; 5/6–12/13 muscular, 4/5 slightly muscular, 13/14 strengthened but translucent.

The oesophagus in iv–x is brown and provided internally with low, white, longitudinal ridges; perhaps slightly widened in v but with no gizzard. In xi–xiii the oesophagus is slender and white, widened abruptly just behind 13/14 (36), the portion in xiii with an appearance of an oesophageal valve. From xiv–xviii however the gut is highly vascular, vertical red stripes especially conspicuous on the coelomic surface of the portion in xiv–xvi, the inner wall with numerous, closely crowded, low, longitudinal, white ridges which become less obvious in xvii–xviii. In xviii quite definitely in front of 18/19 (11) or in xix at various distances from 18/19 (10) the gut is again abruptly widened, though not as conspicuously as at 13/14, and the appearance of both inner and outer walls changes slightly. A definite valve in this region is unrecognizable. The inner wall of the intestine is marked off into small squares by slight longitudinal and circular furrows. No typhlosole.

The dorsal blood vessel (single) is continued anteriorly to and under the supra-pharyngeal ganglia. A supra-oesophageal trunk is usually recognizable from xv to 11/12 but is usually empty anteriorly. Extra-oesophageals are first recognizable in v (anterior to 4/5 apparently continued dorsally and then anteriorly into ii), passing onto the ventral surface of the gut only in xiv or xv, united mesially in xv or xvi, usually unrecognizable behind xvii. A rather conspicuous branch passes laterally from each extra-oesophageal in x–xvi on the anterior faces of the septa. The ventral trunk is continued forwards to the anterior margin of the subpharyngeal ganglia where it bifurcates. No subneural. In x–xiii there are large latero-oesophageal hearts, the connectives with the dorsal trunk red and rather conspicuous, the slender, short branches to the supra-oesophageal usually white. The last pair of hearts is in xiii (35), the left heart of xiii lacking in one specimen. There are commissural loops in v–ix, all loops and hearts passing into the ventral trunk.

Nephridia in xiii are small, the funnels club-shaped (23, not noted in other specimens). There are no nephridia anterior to xiii or in xiv (23), the large nephridia always beginning in xv. The tubules are flattened against the body wall, reaching to or nearly to both septa of a segment and dorsally to *d*. The preseptal funnels are close to the ventral parietes in *ab*.

Testes, in x and xi, are rather fan-shaped. Male funnels are free, with smooth, rounded rims. Seminal vesicles in xi and xii are acinous, vertically placed. Prostates are usually confined to the posterior half of xviii, the nephridia in the anterior half. The ducts of the most mature specimens are slightly more than two mm. long, with marked muscular sheen, straight, sinuous, or slightly looped, but never spindle-shaped. The male deferent ducts pass into the ectal ends of the prostates. On the median face of the prostatic duct there is often visible a cord of tissue that looks like a setal follicle. In two worms setae appeared to be present in the follicles but attempts to dissect out the setae were failures.

The spermathecal duct is shorter than the ampulla, narrowed within the parietes, with large lumen. In fifteen specimens the single, digitiform diverticulum on each spermatheca passes into the median face of the duct close to the parietes. In five worms each spermatheca has a lateral diverticulum of the same size as the median and passing into the duct exactly opposite the median junction. A lateral diverticulum of the same size as the median is present in other specimens as follows: on both left spermathecae (2), on both right spermathecae (3),

on the left posterior spermatheca (6), on the right anterior spermatheca (2), on both spermathecae of ix (1), on three spermathecae (1). In the remaining worm the median diverticula are about half the length of the main spermathecal axis while the lateral diverticula (lacking only on the right posterior spermatheca) are much shorter. In one worm with unidiverticulate spermathecae one diverticulum is bifid.

The longitudinal musculature is uninterrupted over sites of the genital markings.

Remarks.—Spermathecae of several worms from each batch, with and without lateral diverticula, have brownish masses in the ental ends of spermathecal ampullae and diverticula, possibly the last remaining evidences of post-sexual regression. The clitellar region shows no evidence of clitellar regression.

The specimens described above are distinguished from *bermudensis* as follows: (1) a slightly more median location of spermathecal pores, (2) presence of symmetrically paired, longitudinally placed, presetal genital markings on xviii, (3) absence of unpaired, intersegmental genital markings in *aa*, (4) junction of diverticulum with spermathecal duct ental to the parietes, (5) tendency to development of a second and lateral diverticulum on the spermathecal duct, and possibly also by (6) a more ventral location of the nephropores as well as (7) the irregularity of setal ranks in a posterior portion of the body. Such a combination of characteristics appears to be sufficient justification for recognition of a species distinct from *bermudensis* but it is to be remembered that *bermudensis* as now understood is highly variable, comprising a number of *formae* of uncertain status, and that the Florida specimens are aclitellate. Accordingly it is possible that certain characteristics of taxonomic importance may now be unrecognizable on the types of the new species. Nevertheless it appears to be unlikely that with sexual maturity any of the distinguishing characteristics just mentioned will approximate to those of *bermudensis* except for a development of unpaired, intersegmental genital markings-structures which may characterize more than one species of *Pontodrilus*. A satisfactory diagnosis cannot be given until clitellate specimens have been studied.

Genus Pheretima Kinberg, 1867

Pheretima californica Kinberg 1867

Material examined.—New Orleans, Louisiana, August 13–15, 8 clitellate specimens. Southern Biological Supply Co., per U. S. Nat. Mus.

Remarks.—This is the first record of the species from United States since erection on specimens from San Francisco.

Pheretima diffringens (Baird) 1869

Material examined.—Lawn, Fort Myers, Florida, February 19, 1941. 1 clitellate specimen. Prof. W. M. Barrows.

External characteristics.—The first dorsal pore is on (10/11?) 11/12. Genital markings are presetal on vii–ix, midway between intersegmental furrows and setal circles, ca. 2–3 intersetal intervals median to the spermathecal pore lines. Spermathecal porophores are unrecognizable and postsetal markings are lacking.

Internal anatomy.—The intestine begins in xvi just behind 15/16. Hearts of x are lacking, the right heart of ix present. Lymph glands are rudimentary anterior to xxvii but posteriorly are well developed. Unpaired, suboesophageal testis sacs are well above the nerve cord, the ventral blood vessel included. Vasa deferentia of a side come into contact in xii but without uniting at least into xvii. Prostates are lacking but prostatic ducts are fairly well developed, each duct bent into a U-shaped loop. The stalks of the genital marking glands of xviii pass into the parietes just median to the prostatic ducts. The lumen of the spermathecal duct is narrowed in the region of the diverticular junction, slit-like in cross-section entally, more nearly circular ectally.

Remarks.—Seminal chambers of spermathecae are filled with opaque whitish material, testes are large and transversely ellipsoidal but there is no spermatozoal iridescence in seminal chambers, vasa deferentia or on the male funnels.

From information at present available, *diffringens* appears to be the most widely spread of those species imported into this country, directly or indirectly, from China and Japan, having been found from Louisiana to Virginia (no record from South Carolina).

Pheretima hawayana (Rosa) 1891

Material examined.—Greenhouses, Hadley, Massachusetts, January 1941, 3 clitellate specimens. Prof. Esther Carpenter.

Remarks.—The testis sacs are unpaired and suboesophageal, distended by coagluum, the ventral blood vessel on or within the roofs of the sacs, the nerve cord well below the sacs.

Pheretima pingi Stephenson 1925

Material examined.—Kuatun, Fukien Province, China, 3000–5000 feet, July, 1939, 1 clitellate specimen. Min Hsin Li.

External characteristics.—Length 240 mm. Diameter 9 mm. Pigmentation bluish grey, restricted to the dorsum, lacking or scarcely recognizable on transverse, midsegmental bands bearing the setae. First dorsal pore on 12/13. Setal formula: vi/9, vii/8, viii/14, xvii/18, xviii/16, xix/22, 22/ii, 23/iii, 38/viii, 41/xii, 48/xx.

Each spermathecal pore is at the center of a tiny circular, white, opaque area that indents the posterior margin of a transversely placed area of greyish translucence. The translucent areas are on the posterior portions of v–viii, the spermathecal pores about in line with the intersegmental furrows. Prior to removal of the cuticle the pores appeared to be segmental. Each male pore is at the center of a transversely placed porophore of elliptical outline.

Genital markings, aside from those just in front of the spermathecal pores, are on xviii, three pairs. One marking either indents deeply the lateral margin of each male porophore or is actually protuberant from the male porophore close to the lateral margin. Two other markings on each side, somewhat larger but smaller than the male porophores, are just median to the male pore lines, one presetal and one postsetal, the latter in contact with but distinct from the male porophore.

Internal anatomy.—Septum 8/9 is complete but membranous. The first lymph gland is in xvi, on the left side. From xix posteriorly a pair of large glands is present in each segment. Most of the glands have one or more balls of variable size of brownish, granular material within the gland tissues.

The dorsal blood vessel (single) is continued anteriorly underneath the supra-oesophageal ganglia. The supra-oesophageal trunk is unrecognizable posterior to 13/14 and disappears into the dorsal wall of the gut in ix. The ventral trunk bifurcates just behind the subpharyngeal ganglia, the branches passing laterally along with the circumoesophageal nervous commissures. Between the anterior bifurcations and the junctions of the commissures of v, two pairs of vessels join the ventral trunk, possibly commissures of iv and iii or their representatives. The subneural trunk is continued anteriorly a short distance in front of the subpharyngeal ganglia before bifurcating. The extra-oesophageal trunks pass onto the ventral face of the gut in ix and just in front of 13/14 pass off laterally. The left trunk passes into the subneural. All commissures of v–vii and the hearts of ix–xiii pass into the ventral trunk. Commissures of v–vii, a pair of large vessels from the gizzard and the hearts of ix open into the dorsal trunk. Hearts of x–xiii open into the supra-oesophageal. In addition each heart of x–xiii is connected to the dorsal trunk by a white cord, probably a blood vessel, but only those of x are red. A pair of hearts belonging to ix is present but the ventral half of the right heart is quite slender.

Testis sacs of x and xi are unpaired and suboesophageal. The ventral blood vessel is included in the sacs and is almost in contact with floors and roofs both. The nerve cord is well below both sacs. The prostatic duct is 2–3 mm. long.

The spermathecal duct (including the parietal portion) is slightly shorter than the ampulla from which it is sharply demarcated. The lumen of the duct is abruptly narrowed in the region of the diverticular junction. The diverticular stalk is nearly as long as the duct, the ellipsoidal seminal chamber about one quarter the length of the diverticulum. Just in front of each spermathecal duct and sessile on the parietes is a glandular mass. In xviii, on each

side, there are three glandular masses, each mass at least partially imbedded in the parietes so that some dissection is necessary to discover the multiple nature of the glands and relationships to genital markings.

Remarks.—The specimen is in very good condition as is indicated by the preservation of the soft lymph glands. The hearts of ix are clearly behind and independent of the membranous postgizzard septum. The last two pairs of spermathecae are anterior to 8/9. In spite of apparent intersegmental location of the spermathecal pores the completeness of 8/9 presence of hearts in x and the genital markings necessitate identification as *pingi*. The relationships of *diffringens* (Baird) 1869 and *pingi* remain undetermined (*vide* Gates 1938).

Pheretima subtilis sp. nov.

Material examined.—Manured ground in low and damp Shan garden, Meung Nawng village, Salween ferry, Pang Long State, Burma, October, 1 clitellate specimen. H. Young.

External characteristics.—Length 60 mm. Diameter four mm. Unpigmented.

The setae begin on ii, on which segment there is a complete circle, and are small, closely crowded, present ventrally on each clitellar segment: vi/39, xvii/23, xviii/16, xix/24, 42/ii, 69iii, 86/viii, 76/xii, 16/xiv, 18/xv, 20/xvi, 76/xx.

The first dorsal pore appears to be on 11/12. The clitellum is annular, yellowish brown, and extends from 13/14 to 16/17; dorsal pores and intersegmental furrows lacking.

Bithecal, spermathecal pores minute and superficial, on 5/6, widely separated. The female pore is median. Male pores are minute, each pore at or near the center of a small, transversely placed, glistening tubercle with rounded ventral face. The tubercle is slightly depressed and partially covered by a thin, lateral flap. The appearance is such as to suggest that the male pore tubercle is on the median wall of a slight parietal invagination with a thin lateral wall.

The genital markings are unpaired, median, transversely placed, slightly protuberant, intersegmental, on 22/23 and 23/24, extending anteroposteriorly almost to the setae, the midventral setae of xxii and xxiv slightly dislocated anteriorly or posteriorly. The anterior marking is about twelve intersetal intervals wide transversely and is slightly larger than the other marking.

Internal anatomy.—Septa 5/6–7/8 are slightly muscular; 8/9–9/10 lacking; 10/11–11/12 slightly muscular.

The intestine begins in xv. Intestinal caeca are simple, small, with smooth margins. There is a slight rudiment of a glandular collar on the oesophagus just behind the gizzard.

Hearts of x are lacking but a pair of hearts belonging to ix is present. Hearts of xi were not found. All hearts of ix, xii–xiii pass into the ventral blood vessel.

The testis sac of x is unpaired and ventral, the sac of xi unpaired and U-shaped, reaching up to the level of the dorsal face of the gut but not bound mesially to the gut. The seminal vesicles of xi are small, included within the testis sac and imbedded in testicular coagulum. Vesicles of xii are medium-sized. Prostates extend through xvii–xix. The prostatic duct is about 3½ mm. long, rather slender, bent into a U-shaped loop, the ectal limb slightly thickened.

The spermathecal duct is slender and somewhat shorter than the ampulla, gradually narrowed within the parietes, the wall rather thin and with annular ridges internally, the lumen abruptly narrowed in the region of the diverticular junction. The diverticulum which passes into the median face of the duct close to the parietes comprises a stalk and an elongately tubular seminal chamber only slightly longer and thicker than the stalk and with spermatozoal iridescence. Both stalk and seminal chamber are looped, the looping in part approximating to a regularly zigzagged arrangement. Because of the looping the diverticulum just reaches up onto the ectal portion of the ampulla.

Genital marking glands are sessile on the parietes.

Remarks.—Difficulty in characterization of the male externalia is due to softening and slight erosion. *P. subtilis* is distinguished from all other bithecal species with pores on 5/6 by the genital markings.

Diagnosis.—Bithecal, spermathecal pores minute and superficial, on 5/6, widely separated. Male pores minute (and invaginate?), each pore on a small tubercle (within a slight parietal invagination that has a thin wall?). Genital markings unpaired, median, transversely placed, on 22/23 and 23/24. Setae present ventrally on all clitellar segments: vi/39, xvii/23, xviii/16, xix/24, 42/ii, 69/iii, 86/viii, 76/xii, 76/xx. First dorsal pore on 11/12(?). Length 60 mm. Diameter 4 mm. Intestinal caeca simple. Hearts of x lacking. Testis sacs unpaired: of x ventral, of xi U-shaped; seminal vesicles of xi included. Spermathecal diverticulum passing into the median face of duct near parietes, looped, in part in a regularly zigzagged manner, stalk about as long as the slightly thicker, elongately tubular seminal chamber. Genital marking glands sessile.

Genus Plionogaster Michaelsen, 1892

This interesting but inadequately characterized genus has been recorded only from the Philippines (four species) and the Moluccas (Ternate, one species) and is supposed (Stephenson 1930, p. 831) to have evolved from that "polyphletic" complex which must be referred to as *Megascolex* for the present. That complex is restricted to two separate areas, one including Ceylon and South India, the other including Australia (southwestern, southern, eastern and northeastern parts), Tasmania, New Caledonia and Norfolk Island.

Plionogaster sp.

Material examined.—Manila, Philippine Islands, October, three aclitellate specimens in fair condition. Zacharias de Jesus per Prof. R. C. Osburn.

External characteristics.—The largest specimen is 160 mm. long, with a diameter of nearly four mm. The other worms are much less than half as long. Unpigmented (3). The prostomium is rather indistinctly marked off but appears to be proepilobous (3).

Setae begin on ii (3) and are small, rather closely crowded, the setal circles with but slight midventral and mid-dorsal gaps, circles of v-x nearer anterior margins of the segments; xviii/19 (smallest specimen); *ca.* 90/xii, *ca.* 56 near the posterior end, viii/30, xvii/23, xviii/10, xix/18 (largest specimen).

Nephropores are first recognizable with some degree of certainty on x though possibly present also on ix, and are in three fairly regular longitudinal series on each side to xviii; one series about on the male pore lines, another about on the midlateral line, and the third nine to eleven intersetal intervals lateral to the mid-dorsal line. In each series the pores are in the setal circles. Toward the hind end the longitudinal ranks are more irregular, the dorsal rank three or more intersetal intervals lateral to the mid-dorsal line, the ventral rank about the same distances from the midventral line, pores of the lateral rank not always recognizable with certainty. The first dorsal pore is on 12/13 (3, but with a pore-like, possibly functional marking on 11/12 of one of the smaller worms).

Spermathecal pores are small, transversely placed slits on 7/8–8/9 (3). The anterior margin of each pore (largest specimen) is swollen, the tumescence with a transversely elliptical outline, sharply demarcated anteriorly by a short, transversely placed furrow. The single female pore is median, slightly presetal, on xiv, at the center of a small tumescence of transversely elliptical outline (1).

The male pores are slightly postsetal, transversely placed, small, crescentic slits (3). The anterior lip of each pore (largest specimen) is protuberant, the tumescence circular in outline, each pore and tumescence at the center of a small, transversely placed, whitened area of epidermal (?) thickening.

The two genital markings, just recognizable on the largest specimen, are of transversely elliptical outline, unpaired, extending laterally on each side about to the male pore lines, presetal on xx and xviii (but crossing slightly or dislocating anteriorly 17/18?). A central portion of each marking has a greyish translucent appearance. On the smallest specimen there is on each side, on xvii and close to 17/18, about in line with the male porephore, a circular area of greyish translucence, indistinctly demarcated, possibly a rudiment of a genital marking.

Internal anatomy.—All septa from 5/6 posteriorly are present; 5/6–9/10 muscular, 5/6–8/9 especially so.

The gut is rather slender and white in vi–ix, the portion in viii slightly widened, of spheroidal shape and with thickened cuticular lining (3). In x–xi the gut is more obviously vascularized and in xii–xviii is widened, with walls striated by red, circular bands. A definite valve is present in the anterior portion of xix but is entirely concealed from view by the anterior portion of the intestine which reaches forward into contact with 18/19 (3). The gizzards are three (2) or four (1), separated from each other by long, thin-walled but white intestinal annuli. The length of each gizzard or intervening annulus is much greater than that of a segment and accordingly this portion of the gut is markedly asymmetrical in each specimen. Segmental locations of the gizzards were not determined but the first gizzard appears to be in or shortly behind xxv. A quite rudimentary typhlosolar ridge is present from xix nearly to the first gizzard but does not become recognizable again until 16 or 17 segments behind the last gizzard, finally disappearing from sight in the region of lxii (1) or lxxxv at a point still in the anterior third of the body (1). Caeca and supra-intestinal glands are lacking.

The dorsal blood vessel (single) is continued anteriorly to the region of iii. The ventral blood vessel is unrecognizable anterior to vi. An unpaired supraoesophageal trunk is visible on the gut from ix into xviii. On the ventral face of the gut at the median line from the last gizzard segment into xix or xv is a vessel which is nearly as large as the ventral trunk, bifurcating in xv or xix, the two branches fairly widely separated from each other but adherent to the gut as far forwards as ix, ventrolateral to the gut in viii, unrecognizable from vii anteriorly. No subneural recognizable (3). In the two smaller specimens there are four pairs of large "hearts" in x–xiii, each pair probably communicating with the dorsal as well as the supraoesophageal trunks. In the other worm "hearts" are present in xii–xiii but commissural vessels of x–xi are much slenderer and white. Blood glands and lymph glands apparently are lacking.

Anterior to 5–6 and at each side of the gut there is a large mass of nephridial tubules, each mass falling apart into three sections with a little probing. In vi–ix, on the anterior face of each septum there is a pair of vertically elongated, anteroposteriorly flattened bands of nephridial tubules. From xii–xvii (x–xi?) four longitudinal series of fairly small, closed, parietal micronephridia are present on each side, a slender duct passing laterally from each nephridium to a longitudinally placed vesicle or bladder which is adherent to the parietes (largest specimen). Posteriorly only three ranks of parietal micronephridia are certainly recognizable on each side and bladders were not found. Beginning with xviii, at least, there is in each segment a pair of meganephridia which reach well towards the mid-dorsal line on the parietes just behind the septa. Slightly lateral to the nerve cord on each side and near the ventral parietes is a preseptal funnel. The neck is very slender and has not been traced with certainty to the nephridial tubule. The duct is also very slender and passes onto the posterior face of the septum where it runs dorsally nearly to the margin of the dorsal blood vessel. Passing posteriorly the size of the meganephridia markedly decreases but preseptal funnels are still recognizable almost at the posterior end. On the dorsal face of the gut from a region behind the last gizzard to the hind end and in contact with the lateral face of the wide and flattened dorsal blood vessel there is on each side a translucent tube, the two tubes with occasional transverse connectives. Lacking blood these tubes should be longitudinal excretory ducts and very delicate whitish threads representing the segmental ducts of the meganephridia, in some segments at least, do pass to the excretory tubes.

Testis sacs of x and xi are of the cylindrical type and contain in addition to testes and male funnels the hearts or commissures and the seminal vesicles of xi. The sacs of the largest specimen are filled with coagulum. Seminal vesicles are also present in xii. Prostates are racemose and confined to xviii. The duct is straight, with muscular sheen, thicker ectally, about one mm. long. In the largest specimen a filament, probably the male duct, rises from the parietes median to the duct and passes into the entalmost portion of the duct. The lumen of the duct is slit-like in cross section.

The spermathecal duct (longest specimen) is shorter than the ampulla and nearly as thick. The diverticulum, usually shorter than combined lengths of duct and ampulla, is rather slenderly club-shaped and passes into the duct close to the parietes. The diverticular lumen is large with numerous thin but relatively rather high annular (? or spiral) ridges on the inner wall of the diverticulum. In one of the smaller specimens the spermathecal diverticula are about as long as the main spermathecal axes.

Remarks.—The number of intestinal gizzards, shape of the spermathecal diverticulum, symmetry and location of genital markings and number of longitudinal ranks of micronephridia are the characteristics hitherto used for specific diagnosis and identification in the genus *Plionogaster*. So little material has been available for study that the value of these characteristics is uncertain. Number of gizzards may be variable as in the Moniligastridae. A tubular diverticulum may be distended entally by spermatozoa after copulation so as to be more or less club-shaped. Genital markings may be variable or unrecognizable except at full maturity. The taxonomic value of numbers of micronephridia is unknown and in any case such characteristics must be used with considerable caution in view of the difficulty in recognition of nephropores, the fragility of the nephridia and the occasional fragmentation or even complete disintegration of tubules (perhaps partly as a result of handling during examination of externalia) in specimens that otherwise appear to be very well preserved.

P. horsti (Beddard) 1886 and *P. sivickisi* Stephenson 1933, the two species hitherto recorded from Manila, apparently are distinguished from each other mainly by the genital markings, paired or lacking in *sivickisi*, both paired and unpaired in *horsti*. From those species the present worms may be distinguished by the presence of unpaired genital markings alone. If however there is no intra-specific variation as to number of gizzards, two species are represented in the new material. *P. jagori* Michaelsen 1892, the species supposedly characterized by four intestinal gizzards has paired genital markings only.

Definition of the genus merely as micronephridial (Michaelsen 1900 and Stephenson 1930) is obviously incorrect. In view of the condition of the specimens and the limited material available an accurate diagnosis is still impossible but the following is suggested tentatively: Quadrithecal, spermathecal pores on 7/8–8/9. Female pore median, on xiv. Male pores on xviii. Setae perichaetine. Clitellum annular (?), on xiv–xvi (?, dorsal pores, intersegmental furrows and setae?). Nephropores in setal circles, in three to six (?) longitudinal ranks from ix posteriorly. Unpigmented. All septa from 5/6 present. Gizzards three or four in a region of the intestine from xxv posteriorly, a regressive oesophageal gizzard in viii; intestinal origin in xix, typhlosole rudimentary, interrupted in gizzard region; no calciferous glands. Hearts latero-oesophageal in (x–xi)–xiii; extra-oesophageals pass onto ventral face of gut in ix, unite mid-ventrally in xv–xix, the united trunks continued posteriorly into gizzard region; no subneural. Excretory organs: one pair of open, enteronephric meganephridia with preseptal funnels from xviii posteriorly, opening into paired and fairly widely separated, supraintestinal ducts with transverse connectives; three to six (?) irregularly longitudinal ranks of closed, exonephric parietal micronephridia from ix posteriorly on each side, each nephridium with a longitudinally placed bladder (?); from ix anteriorly nephridia in clusters on anterior faces of septa. Holandric, seminal vesicles in xi and xii. Prostates racemose.

The gizzard in viii and the paired supra-intestinal excretory ducts are similar to conditions in *Pheretima* but the open enteronephric meganephridia are like those of *Lampito*. The supra-intestinal excretory ducts are more widely separated than in *Pheretima*. Intestinal gizzards are known elsewhere only in the Lumbricidae.

Genus Diplocardia Garman, 1888

Diplocardia is of particular interest because of marked, intrageneric variation in characteristics usually uniform in Megascolecid genera or even through groups of genera of considerable size. The male pores, almost always on xviii in the former subfamily Megascolecinae—as well as in considerable sections of the Acanthodrilinae, Octochaetinae and Ocnerodrilidae, may here be on any segment from xviii to xxi. The primitive condition, location of male pores on xviii, is found only in one species, a Mexican form. Species with male pores on xix are recorded from southern Florida north into Ohio, Indiana, Illinois and Missouri. One species with male pores on xx is known with certainty only from Nebraska with doubtful records (possibly of other species) from Illinois and Ohio. Species with male pores on xxi have been found in Texas and Lower California.

The intestinal origin, so often in xv in the Megascolecidae, may in *Diplocardia* be in any segment from xiv or xv to xix or xx, and apparently without intraspecific variation. In xiv (? but perhaps doubtfully and possibly rather in xx, *vide* Eisen, 1900), in *koebelei* (Mexico); in

xv, in *keyesi* (Lower California); in xvi, in *verrucosa* (Nebraska); in xvii, in *communis* (Illinois), *caroliniana* (North Carolina), *floridana*, *mississippiensis*, singularis (Illinois), *udei* (North Carolina), and two new species (from Texas and Tennessee); in xviii, in *eiseni* (Florida), *longa* (Georgia), *michaelseni* (North Carolina), *riparia* (Illinois), and two new species (from Florida and Tennessee); in xix, in *texensis;* possibly in xx, *koebelei* (Mexico). Assuming that an intestinal origin in xv is primitive and that the greatest departure therefrom is the most highly specialized, the primitive species is Mexican while the most specialized are in Texas and possibly Lower California.

The primitive spermathecal battery presumably comprises four spermathecae and quadrithecal species have been found from Mexico to Nebraska while sexthecal species are now known only from an area including Georgia, North Carolina, Tennessee and Illinois. Species with last hearts in xii are present from Mexico to Nebraska but those with hearts in xiii have been found only in the area from Florida and Texas north through Georgia and Mississippi into Illinois.

Smith (1924) commented on the absence of calciferous glands in species from the north central states and the presence of such glands or high lamellae in forms from the southern states, North Carolina to Florida and Mississippi. New species from a more southern portion of Florida and from Texas, however, have as rudimentary lamellae as any of the more northern forms.

Designation of known species as definitely primitive or highly specialized is impossible, the one with primitive intestinal origin has the greatest degree of specialization in posterior dislocation of male pores, while the species that is primitive with regard to location of male pores may have the most posterior intestinal origin. Species with greatest development of calciferous glands (internal) have male pores on xix only slightly behind the primitive location.

Diplocardia alba sp. nov.

Material examined.—Roadside ditch, Yellow Fern Creek, Fort Myers, Lee County, Florida, January 21, 1941, 12 partially clitellate or clitellate specimens. Prof. W. M. Barrows. Roadside ditch, Fort Myers, Florida, February 19, 1941, 6 small juveniles and 31 partially clitellate or clitellate specimens. Prof. W. M. Barrows.

External characteristics.—Length to 75 mm. Diameter 2 mm. Unpigmented. Prostomium apparently epilobous but with no transverse furrow at posterior edge of tongue. Nephropores are not certainly recognizable but appear to be on *d*. Setae begin on ii on which all four couples are present; on xxiii, $ab<cd<bc<aa$, $dd\ ca.=\frac{1}{2}C$; ventral setae of xviii–xx unrecognizable (16), on viii–ix usually deeply retracted into the parietes and with the tips just visible in the epidermis or invisible, in which case the openings into the setal follicles are clearly visible. The first certainly functional dorsal pore is located on 10/11 (4), 11/12 (11) or 12/13 (1) but one or two rather pore-like markings anteriorly may represent functional pores. The clitellum is light yellow, slightly protuberant when fully developed, annular, extending from 12/13 to 17/18 (16), the clitellar coloration lacking in *aa* on xiii and xvii; sites of intersegmental furrows slightly indicated (more so ventrally), dorsal pores lacking, setae present.

Quadrithecal, spermathecal pores minute, about the same size as apertures of setal follicles, on viii and ix, in *ab*, usually slightly nearer to *b* than *a*, the anteroposterior location variable; slightly behind 7/8 and 8/9 (21); slightly behind 7/8, midway between 8/9 and setal arc of ix (8); slightly behind 7/8, just in front of setal arc of ix (5); midway between 7/8 and setal arc of viii, on or just in front of setal arc of ix (9). Female pores are minute, anteromedian to *a* and slightly nearer to the *a* setae than to each other (16), on an indistinctly demarcated, transversely placed area of epidermal whitening. On one specimen there is a single median female pore.

A male genital shield is not definitely marked off but an area between the setal arcs of xiii and xx may be very slightly protuberant. Seminal grooves are nearly straight, fairly deep—the median margins especially tumescent, in *ab*, between setal arcs of xviii and xx. Prostatic pores (not always recognizable) are at the termini of the seminal grooves. Male pores are minute, each pore on a tiny, knob-like protuberance from the lateral wall of the seminal groove,

the knob about on the setal arc of xix. There are no genital markings but a tiny, circular area around each aperture of the ventral setal follicles of viii and ix is greyish translucent and within a small, circular area of slight tumescence.

Internal anatomy.—All septa are present from 5/6; 7/8–9/10 most opaque but no septa thickly muscular.

Gizzards are in v and vi (16). The gut is slightly widened at 12/13. In xiv–xvi on the inner wall of the gut there are very low, longitudinally placed lamellae which are less obvious in xiii though the outer wall in that segment is as vascularized as in xiv–xvi. The intestine begins in xviii (10), the oesophageal valve anteriorly in the same segment. The typhlosole is represented by a very low, whitish ridge which begins in xviii and is unrecognizable behind lxvi or lxxvi (worm with 131 segments).

The dorsal blood vessel is doubled from xvii through vii (13) or vi (1), the doubled portions widely separated, the trunk simplex in the region of the septa. The trunk may be slightly doubled in xviii and perforate in xix (2) but apparently is never doubled anterior to 5/6. A supra-oesophageal trunk is unrecognizable, the extra-oesophageals recognizable only in v–vi beneath the gizzards and even there empty. Apparently no subneural (10). Vascular loops in x–xiii are larger than anteriorly and with two branches dorsally from each loop, one to the dorsal trunk and the other to the gut but both branches are filamentous and without blood. The last pair of hearts is in xiii (16).

Nephridia begin in ii. Preseptal funnels have been found only in the posterior segments and are close to the ventral parietes in *ab*.

Testes, free in x and xi, are bifid or trifid and flattened. Male funnels are large and with marked iridescence. Coelomic cavities of x and xi are filled with coagulum. Seminal vesicles are in ix and xii (16), the posterior larger. Prostates are in xviii or xviii–xix and xix–xx and are fairly short, not much longer than the ducts, flattened. Prostatic ducts are over two mm. in length, with marked muscular sheen, C-shaped with a short and narrowed ental portion in one or two U-shaped loops. The male deferent ducts of a side come into contact posteriorly in xii and from thence on may be looped, the loops protuberant from the parietes, passing laterally but close to the prostatic ducts of xviii and into the parietes in xix midsegmentally, the ducts united just within or just prior to entrance into the parietes.

The spermathecal duct which is clearly marked off from the rather heart-shaped ampulla is narrowed within the parietes in a rather conical fashion and widened entally from just below the region of the diverticular junction. The lumen is large entally and elliptical in cross section but ectally is narrow. The pendent diverticulum which opens through a slight conical protuberance apparently on the lateral face of the duct (spermathecae usually slightly twisted) near the ampulla by a pore on a small tubercle, vertical ridge or prominence, comprises an ellipsoidal seminal chamber and a very short and slender stalk almost at right angles to the chamber. Occasionally the spermatozoa in the seminal chamber are in one large ventral and one, two or three smaller masses dorsally, slight furrows on the surface of the stalked end of the diverticulum partially marking off small lobes.

Copulatory setae (ventral couples of viii–ix) are curved slightly in a sort of arc, the tip somewhat hastate but with a rather shallow, scoop-shaped depression on the side of arc concavity, ornamentation of 12 to 16 irregularly and widely interrupted circles of closely crowded, fine spines. At the margins of the shafts light transparent spots are visible just ectal to the circles of spines and the margin is incised. Setal follicles are present within the parietes on the median faces of the prostatic ducts but scarcely reach into the coelomic cavities. Attempts to remove the setae failed.

Abnormality.—One specimen lacks the right anterior prostate and duct.

Remarks.—The intestine of one specimen, aside from a brown flecked slime and a few scattered bits of black organic matter, is filled with quartz pebbles.

Of those species of *Diplocardia* with male pores on xix, only *eiseni* (Michaelsen) 1894 and *mississippiensis* Smith 1924 have hearts in xiii and a doubled dorsal blood vessel. *D. alba* is distinguished from *eiseni* by the presetal location of the spermathecal pores and absence of high, lamellar folds in the calciferous section of the gut, and from *mississippiensis* by the absence of calciferous glands, the rudimentary typhlosole and the simple spermathecal diverticulum.

D. eiseni and *D. floridana* Smith 1924 are the only species hitherto reported from Florida. From *floridana, alba* is distinguished by the rudimentary typhlosole, the presence of hearts in xiii, the simplex condition of the dorsal trunk in xx–xxv, absence of calciferous glands and the simpler spermathecal diverticulum.

Diagnosis.—Male pores on xix on setal arc, on very small knobs on lateral walls of straight seminal grooves extending in *ab* between setal arcs of xviii and xx. Prostatic pores at termini of seminal grooves and on setal arcs of xviii and xx. Quadrithecal, spermathecal pores on presetal portions of viii and ix in *ab*. Female pores anteromedian to *a*. Setae: $ab < cd < bc < aa$, *dd ca.* = ½ C, ventral setae of viii–ix slightly arced, tip rather hastate but slightly hollowed on concave side of arc, ornamentation of irregularly interrupted circles of very fine spines; (penial setae?). Clitellum annular, 12/13–17/18. First dorsal pore on 10/11–11/12. Unpigmented. Length to 75 mm. Diameter 2 mm.

Gizzards in v–vi; no calciferous glands, longitudinal lamellae in xiv–xvi low; intestine begins in xviii, typhlosole rudimentary. Dorsal blood vessel double in vii–xvii; last hearts in xiii. Spermathecal duct as long as ampulla, a pendent diverticulum with ellipsoidal seminal chamber opening by a very short and slender stalk through a conical protuberance on lateral face of duct into a widened ental portion with large lumen.

Distribution.—Known only from the type locality, Fort Myers, Lee County, Florida.

Diplocardia fusca sp. nov.

Material examined.—Agricultural soil, Fort Worth, Texas, March, 1941, 1 aclitellate specimen. Prof. R. F. Chandler, Jr.

External characteristics.—Length (strongly contracted) 292 mm., the last eight segments uniformly small and possibly regenerate. Diameter 8 mm. There is at least one metameric abnormality in the posterior half of the body. The dorsum of the anteriormost forty mm. is a fairly dark brown, but posteriorly the color rapidly disappears until the dorsum appears to be white though scattered brown flecks are still recognizable for some distance under the binocular, the pigment again recognizable and fairly dense on the dorsum of the last twenty mm. The prostomium is slightly proepilobous. From ii posteriorly there are two deep secondary furrows on each segment. From vi posteriorly a tertiary furrow is present on each of the first and third secondary annuli. Passing posteriorly these tertiary furrows become as deep as the secondary furrows. Nephropores are slightly dorsal to *d*, on the anterior margins of the segments from iii posteriorly. A pair of pit-like depressions on ii probably are nephropores as nephridia are present in ii. Setae are unrecognizable wholly or in part on the anterior segments. On xxiii the formula is approximately as follows: $ab : cd : aa : bc :: 1 : 1 : 4 : 7$, *dd ca.* = ½ C. The first dorsal pore appears to be on 12/13 but there is a pore-like marking on 11/12.

Spermathecal pores are quite small, transversely placed slits on vii and viii *ca.* on *a*, very slightly behind 6/7 and 7/8. Female and male pores are unrecognizable. Prostate pores are transversely slit-like, at the termini of the seminal grooves on the setal arcs of xviii and xx and somewhat median to *b*.

Seminal grooves are slightly concave laterally, reaching to the setal arcs of xviii and xx about at mid *ab* and mesially on xix to *a*. A genital shield is not marked off, a median region between the *a* lines of xix slightly depressed. Setae *a* and *b* of xviii and xx are closely paired and just median to the prostatic pores, the *a* setae slightly displaced laterally, the *b* setae even more displaced mesially. Ventral setae of xviii if present are unrecognizable. Transversely placed, anteroposteriorly short tumescences reaching laterally on each side nearly to *a* on 17/18, 18/19, 19/20 and 20/21, with smooth, glistening, convex surfaces, may be genital markings.

Internal anatomy.—Septum 4/5 is present but delicate, 5/6 strengthened but transparent, 6/7–10/11 thickly muscular, 11/12 muscular and opaque but not as thick as 10/11, 12/13 strengthened but slightly translucent, 13/14 and several succeeding septa strengthened but increasingly transparent.

Gizzards are in v and vi. In vii–ix the inner wall of the oesophagus is marked off into low, longitudinal, white ridges. Midsegmentally in each of segments vii–ix and transversely placed on the dorsal surface of the gut is a small but quite obvious, lobulated ridge of a slightly iri-

descent (glandular?) material. There are no lamellae or calciferous glands but in xi–xiii the inner wall of the oesophagus is provided with numerous, closely crowded, dark red, papillose projections, often pear-shaped or shortly ridge-like. The projections are less marked in x and decrease in size gradually in xiv to mid xv where they end. On the floor of the gut at the median line in xi–xvi there is a fairly high, dark red ridge somewhat like a typhlosole. The inner wall of the gut in the posterior half of xv and in xvi is smooth and with a rather velvety appearance. The oesophageal valve is in the anterior portion of xvii, the intestine beginning abruptly in the posterior half of xvii. The typhlosole begins abruptly in xxii and is of the simple, lamellar type, about two mm. high, the lumen slit-like in cross section and filled with blood. The typhlosole gradually decreases in height posteriorly and is unrecognizable behind cxxiv at a point 138 mm. from the anterior end. Presumably as a result of the strong contraction of the worm the typhlosole is folded in a regularly zigzagged manner. On the floor of the gut in xlviii–lxxxvi, just lateral to the median line on each side, there is a well marked, dark red, longitudinal ridge.

The dorsal blood vessel is doubled in v–xv and anterior to 4/5 remains doubled until it disappears from sight in the pharyngeal bulb. In xvi–xviii the doubled portion is considerably shortened. From xix the dorsal trunk is perforated midsegmentally, the perforations at first large enough to permit passage of a pin but filled with chloragogen. Posteriorly the perforations become smaller and eventually disappear as the trunk loses its broad, flattened appearance and becomes more nearly circular in section. The supra-oesophageal trunk disappears into the gut slightly behind 13/14 and is continued forwards to 9/10. Anterior to that septum the supra-oesophageal appears to be continued as a somewhat irregular, small vessel to 6/7 but is paralleled on one side from 9/10 to 6/7 by a slightly smaller vessel. The extra-oesophageals pass onto the ventral surface of the gut in xi and unite mesially in xiii, passing through 4/5 close to the ventral parietes and then turning upwards to unite just underneath the dorsal trunk so that the vertical portions in front of 4/5 at first look like commissures from the dorsal vessel. Several large vessels from the dorsal face of the pharyngeal bulb pass into the extra-oesophageals and also a large vessel on each side from the ventral parietes. The extra-oesophageals are in communication with each other through short, transverse connectives in vii and ix. The ventral trunk bifurcates just in front of the suboesophageal ganglia, the two branches passing laterodorsally. There is no subneural trunk. Hearts of x–xiii are latero-oesophageal, opening into both dorsal and supra-oesophageal trunks. Smaller loops, in v–ix, open only into the dorsal trunk. All loops and hearts pass into the ventral blood vessel.

Nephridia begin in ii and gradually increase in size posteriorly but in xxiii reach only just beyond *d*. The necks (preseptal) which are long enough to reach half way or more towards the anterior septa are close to the ventral parietes at or just lateral to *b*. The neck terminates entally in a small, dark annulus of the same diameter as the neck so there is practically nothing of a "funnel" shape.

Testes are fairly large, bushy masses free in x and xi. Male funnels are rosette-shaped, those in xi with a very slight iridescence, possibly spermatozoal. Seminal vesicles, in ix and xii, are medium-sized and acinous. The prostates are not confined to single segments. The ducts are three to four mm. long, slender, nearly straight, with slight muscular sheen.

The spermathecal duct is of about the same length as the (probably strongly contracted) ampulla and only slightly narrower. Ectally the lumen is transversely slit-like in cross section but entally is widened and rather star-shaped in cross section due to the presence of several longitudinal ridges that nearly meet in the center. The lateromesially flattened diverticulum is on the anterior face of the duct and connected to the septum next in front by a mesentery. Only the ental half is attached to the duct. In the anterior portion of the diverticulum are several small seminal chambers, each apparently opening into a vertical passage (circular in cross section) located in the portion next to the duct and which opens through a single pore into the duct near the ampulla.

Iridescent material, probably spermatozoal, is present in some of the seminal chambers though this was discovered only on dissection.

Remarks.—Lips of spermathecal and prostatic pores are in apposition, the pores recognizable only after slight traction in the neighboring region has separated the lips. Before this

was observed very definite grey, translucent spots on 6/7 and 7/8 (as well as on 8/9) just in front of the real spermathecal apertures were suspected of being sites of the pores. Inability to remove cuticle from a recently preserved specimen may explain failure to recognize male and female pores.

The clearly visible nephropores enabled confirmation of a prior segmental enumeration, a matter otherwise of some difficulty because of the depth of secondary and tertiary furrows and also because of the absence or invisibility of setae anteriorly.

The vasa deferentia were not traced and no effort was made to remove the penisetal follicles of xviii and xx, or what appeared to be follicles of the ventral setae of xviii, or the ventral setae of vii–ix.

The spermatozoal iridescence in the seminal chambers of the spermathecae would appear to indicate a postsexual condition, but no evidence of clitellar regression was recognized.

D. fusca is perhaps as close to *alba* as to any species now known and is distinguished therefrom by the larger size, the location of the spermathecal pores on vii and viii, the more anterior intestinal origin, the larger typhlosole and characteristics of the spermathecal diverticulum.

One other species, *D. texensis* Smith 1924 has been recorded from Texas (Chillicothe) but is clearly distinguished from *fusca* by location of the prostates and male pores on xx-xxii, absence of hearts of xiii, the simplex condition of the dorsal blood vessel, as well as other important characteristics.

Although a satisfactory diagnosis cannot be given until clitellate specimens have been examined *D. fusca* is clearly distinguished from all other species by its large size and from other quadrithecal species by the location of the spermathecal pores on vii–viii.

Diplocardia gracilis sp. nov.

Material examined.—(Lebanon?), Tennessee, October 6, 1914, 1 clitellate specimen. Prof. H. A. Hill per U. S. Nat. Mus.

External characteristics.—Length 68 mm. Diameter two mm. Pigmentation unrecognizable (alcoholic preservation). The prostomium is proepilobous, the indentation of i slight. Secondary furrows are recognizable only posterior to the clitellum, one presetal and one postsetal on each segment. Nephropores, at least from v posteriorly, are on or slightly dorsal to *d*. Setae begin on ii on which all four couples are present; on xxiv, *ab ca.* = *cd*, *bc* < *aa*, *dd ca.* = ½ C. The first dorsal pore is on 9/10. Clitellar coloration, a faint yellowish, is recognizable with the binocular on xiv–xvii, the epidermis of those segments clearly though but slightly thickened at the mid-dorsal incision as well as midventrally in *aa*.

Quadrithecal, spermathecal pores minute, postsetal on viii and ix, slightly nearer the setal arcs than to the intersegmental furrows, slightly median to *b* except the left posterior pore which is about at mid *ab*. The margin of each aperture is opaque, the pore centrally located in a tiny, slightly depressed, circular area of greyish translucence. Female pores are very slightly median to *a* and about midway between 13/14 and the setal arc.

Seminal grooves are nearly straight, just median to *b*, reaching nearly to the setal arcs of xviii and xx. Male pores are in the seminal grooves slightly behind 18/19 on tiny rounded tumescences. Prostatic pores are just lateral to the termini of the seminal grooves and about on *b*. Just median to the prostatic pores and about at the ends of the seminal grooves are the very closely paired apertures of the penisetal follicles of xviii and xx.

Genital markings are transversely placed areas of brownish translucence in *aa* at the posterior margins of xxi–xxvi (furrows 21/22–22/23 invisible ventrally). On each of these areas there are visible, but only with right direction of light, three, tiny, circular opaque spots.

Internal anatomy.—None of the septa are especially muscular.

Gizzards are in v and vi. The gut is slender in ix–xvii, the inner wall in x–xv provided with low, papillose protuberances in several longitudinal rows, calciferous glands and lamellae lacking. The intestine begins abruptly in mid xviii, the oesophageal valve anteriorly in xviii. The typhlosole which begins in xx is fairly high and thickest ventrally, rather oval in cross section, the lumen—filled with blood—also oval in section.

The dorsal blood vessel is single. Extra-oesophageal trunks are present. No subneural trunk. The last hearts are in xii.

Holandric, the male funnels small and with thick, rounded rims. Seminal vesciles are acinous and in ix and xii. Prostates are restricted to xviii and xx, the ducts *ca.* one mm. long, shorter than the glands, nearly straight, slender, with slight sheen. Male deferent ducts of a side pass in xviii close to the prostatic ducts laterally and then into the parietes just behind 18/19, uniting within the body wall. Two penisetal follicles project conspicuously into the coelomic cavities just median to each prostatic duct but are less than half as long as the prostatic ducts. The main portion of the shaft of a penial seta is nearly straight but an ectal portion is slightly curved the arc of curvature variable, several setae bent at region of curvature. The tips of some are bifid. One seta, apparently the least worn, has a deep incision marking off slightly ental to the tip a large, triangular tooth. The bifid appearance of the other setal tips is then presumably due to erosion of the real tip. Ornamentation sparse, of several circles of fine spines, not always recognizable (worn?).

The spermathecal duct is about as long as the ampulla from which it is clearly marked off, narrowed in the parietes and widened from below the diverticular junction entally. The single diverticulum is lateromesially flattened, the pointed ventral end reaching to the parietes, the dorsal half adherent to the anterior face of the duct, opening into the duct entally but quite definitely below the ampulla.

Ventral setae of viii and ix but not of vii and x are enlarged, without noduli, slightly curved, with simple tips, ornamentation of three or four longitudinal rows of four or five elongated but slender spines. Near each spine there is a longitudinal groove or slit (possibly an artefact).

The body wall is uninterrupted over sites of the genital markings but in section the epidermis (or an outer portion) of the white circles appears to be transparent thus permitting recognition of a small, opaque body, possibly a gland or entral modification of the epidermis.

Remarks.—Spermatozoal iridescence on the male funnels indicates sexual maturity but there is no iridescence in the spermathecal diverticula and the clitellum certainly does not appear to be fully developed. The bending of ectal portions of the penial setae may have been produced in removal of the setae but erosion of tips and ornamentation may be evidence for believing that the worm is in a postsexual stage of clitellar regression.

D. gracilis with four spermathecae, single dorsal blood vessel and last hearts in xii is close to *D. udei* Eisen 1899 from which it is distinguished by the following characteristics: (1) proepilobous prostomium, (2) location of first dorsal pore on 9/10, (3) absence of genital markings in *bc*, (4) presence of genital markings in *aa*, (5) postsetal location of spermathecal pores, (6) presence of a definite, external spermathecal diverticulum, (7) absence of copulatory setae in x, (8) intestinal origin in xviii, and possibly also by differences in the setal formula, shape and ornamentation of copulatory and penial setae.

Diplocardia ornata sp. nov.

Material examined.—(Lebanon?), Tennessee, October 6, 1914, 7 aclitellate and 49 clitellate specimens. Prof. H. A. Hill per U. S. Nat. Mus.

External characteristics.—Length 70–110 mm. Diameter 2–3½ mm. Pigmentation unrecognizable (alcoholic preservation). Prostomium tanylobous (53). On v or vi to xii each segment may have two secondary furrows, one presetal and one postsetal. Posterior to the clitellum secondary furrows are usually unrecognizable. Nephropores from iii posteriorly are on or slightly dorsal to *d*, on ii in line with furrows forming the lateral margins of the tongue of the prostomium or slightly ventral thereto. Setae begin on ii on which all four couples are present; on xxiv, $ab < cd$, $bc < aa$, *dd ca.* = ½ C. The first dorsal pore is on 10/11 (25) but on sixteen of those specimens there is a more or less pore-like marking on 9/10 which may indicate on a few of the specimens presence of a functional pore. The clitellum is reddish brown and, with greatest development, extends from 12/13 to 18/19 but may be lacking or almost unrecognizable on xiii and xviii and even with full development on those segments the clitellar epidermis is much thinner than on xiv-xvii, lacking in *aa* which is always white. Intersegmental furrows more or less definitely indicated, dorsal pores usually lacking, setae present.

Sexthecal, spermathecal pores tiny (slightly larger than the female pores), transversely or diagonally placed slits on the anterior margins of vii–ix just behind the intersegmental furrows, on or just lateral to *a*, each pore on a slightly tumescent, greyish translucent area often mark-

edly protuberant like a small tubercle and reaching to the intersegmental furrow in front. On one worm the right pore of viii is on *b*. Female pores are anteromedian to *a*, closer to each other than to *a* or nearer to *a*, nearer the setal arc than 13/14, on a transversely placed area of marked epidermal thickening that may reach laterally to *a* or *b*, the outline elliptical.

Seminal grooves are in *ab*, usually perhaps nearer to *b*, nearly straight (apparently often distorted by some local contraction) and reaching almost to the setal arcs of xviii and xx. Male pores are in the seminal grooves behind 18/19 and may or may not be on tiny, rounded tubercles which vary in position from just behind 18/19 to level of a presetal secondary furrow. A genital field is not marked off but lateral or median or both margins of the seminal grooves may be more or less markedly tumescent or each groove may be within a longitudinally placed area of tumescence as in certain species of *Dichogaster* or some of the Ocnerodrilids, or tumescence may be recognizable only in nearly circular areas around the termini of the seminal grooves. Prostatic pores are just lateral to the termini of the grooves, about on *b*, the very closely paired apertures of the peni-setal follicles at the termini of the grooves.

Genital markings of 20 specimens are located as follows: 15/16 (4), 16/17 (20), 17/18 (20), 20/21 (4), 21/22 (19), 22/23 (19), 23/24 (18), 24/25 (5). These markings are recognizable and their characteristics determinable only with some difficulty. On the clitellar region with recognizable individual peripheral and central portions (both opaque), paired, closely in *aa* on 15/16, more widely separated on 16/17 (with centers on or close to *a*), still more so on 17/18 (with centers on or near mid *ab*). Posteriorly markings may have much the same appearance as anteriorly and be also widely separated, but more usually all that may be recognized are transversely placed areas of brownish translucence, at first in *bb* but posteriorly contracting into *aa*. On each of these areas, with proper illumination there are recognizable tiny, sharply demarcated, circular areas of opacity, of which there may be four, three or two, or occasionally one—asymmetrical, in transverse rows.

Internal anatomy.—Septa 5/6–6/7 are strengthened but transparent to translucent, 7/8–10/11 muscular but not especially thickened, 5/6–8/9 funnel-shaped.

Gizzards are in v–vi (10) but 6/7 comes into contact mesially with the gut at or just in front of the anterior margin of the posterior gizzard and must be peeled off carefully before the correct location is recognizable. The gut in ix–xvi usually is rather slender. On the floor of the oesophagus in x–xiv is a fairly high longitudinal ridge gorged with blood (10). On the inner walls of the gut in x–xiii there are numerous papillose protuberances (gorged with blood) with a recognizable tendency to arrangement in longitudinal rows but lamellae and calciferous glands are lacking (10). The intestine begins in xvii (10), the oesophageal valve anteriorly in xvii or at the region of attachment of 16/17. The typhlosole begins in xix or xx (10) and is a fairly high (*ca.* one mm.), simple lamella, with lumen vertically slit-like in cross section and filled with blood, gradually decreasing in height posteriorly and unrecognizable behind lxvii–lxx.

The dorsal blood vessel is single (10). A supra-oesophageal trunk is recognizable between 8/9 and 12/13. Extra-oesophageal trunks pass onto the gut in ix and unite mesially in xiii or xiv, anterior to 4/5 with one large branch close to the ventral parietes forwards to i, and smaller branches to the lateral and dorsal faces of the pharyngeal bulb. The ventral trunk bifurcates just anterior to the subpharyngeal ganglia. No subneural trunk (10). Hearts of x–xii are latero-oesophageal but the branch to the dorsal trunk is slender and white. The last pair of hearts is in xii (10). In xiv on each side there is a fairly large, longitudinally placed vessel on the parietes latero-ventrally. In xiii that vessel turns dorsally and eventually passes to the ventral face of the gut and possibly to the extra-oesophageal, a loop occasionally reaching up nearly to the dorsal trunk with something of an appearance of a heart.

Nephridia, behind the clitellum, reach laterally on the parietes about to level of *d*, funnels small, close to the ventral parietes slightly lateral to *b*. Funnels of nephridia of ii have not been found.

Holandric, male funnels rosette-shaped and with brilliant spermatozoal iridescence. Seminal vesicles are in ix and xii, acinous (10). Prostates are relatively large and extend through several segments, as many as ten to twelve. The ducts are slender, with slight sheen, *ca.* two

mm. long, looped entally, slightly longer (*ca.* ½ mm.) than the penisetal follicles. In xviii the male deferent ducts of a side pass just lateral to the prostatic duct, penetrating into the parietes slightly behind 18/19, uniting just within the body wall.

Penial setae are more than one mm. long, variously curved but not S-shaped, the tip slightly flattened on opposite sides, ornamentation of rather widely separated circles of saw-teeth-like appearance. Setae are often bent, wrinkled, with tips broken off, occasionally with slight fibrillation of the ectalmost portion, the ornamentation apparently more or less eroded.

The spermathecal duct is narrowed rather abruptly near the parietes, rather conical within the body wall, sharply marked off from the wider, often rather heart-shaped ampulla. On the anterior face of the duct near the ampulla is a thick-walled, hemispheroidal protuberance which is continued ectally for a short distance within the wall of the duct and finally opening into the duct lumen. Immediately lateral to that chamber is a lateromesially flattened, vertically placed diverticulum with pointed lower end reaching to or nearly to the ventral parietes, adherent to the duct by the upper half and apparently opening into the duct lumen independently. When filled with spermatozoa slight constrictions may mark off two, three, four or five lobes.

The ventral setae of vii-ix are sigmoid but ornamented ectally by short, transversely placed rows of fine spines. These setae are slightly larger than the ventral setae of vi and x which are similarly ornamented.

The longitudinal musculature is uninterrupted over the sites of genital markings which are areas of marked epidermal thickening.

Abnormalities.—One specimen has a spiral metameric abnormality in the clitellar region; right spermathecal pore of viii lacking, clitellum one segment further anteriorly on the right side and two segments further posteriorly on the left side with abrupt demarcation on the three segments exactly at the mid-dorsal line, seminal grooves on two segments only and one segment behind on the left side, right female pore on xiii, right heart of xii lacking, a seminal vesicle in xi—right side, right posterior vesicle rudimentary, right ovary in xii, left posterior prostate lacking, right posterior prostate rudimentary.

In another worm the ampulla of the left anterior spermatheca is completely divided into three lobes, the median and lateral ellipsoidal, smooth-surfaced and distended by hard translucent material, the middle lobe slightly larger and more irregular.

Parasites.—On the cuticle of several specimens there are numerous small, whitish cysts of rather variable size and shape. Each cyst has a thick rind composed mainly of radially placed, needle-shaped crystals apparently of calcium carbonate. Occasionally cysts are closely crowded into plates a millimeter or so in diameter in which definite boundaries of cysts are indistinct or unrecognizable.

Remarks.—Genital markings are no more easily recognized on fully sexual specimens than on the type of *gracilis*.

Gizzards have been located in vi–vii in two species of *Diplocardia* but in one of these the location has been corrected by Stephenson (1933) to v–vi. In the remaining form location in vi–vii may need confirmation, especially in view of the confusion that might be caused by the adherence of funnel-shaped septa to the gizzards.

With six spermathecae, single dorsal blood vessel and last hearts in xii, *D. ornata* is close to *D. singularis* (Ude) 1893 and *D. caroliniana* Eisen 1899 from which it is distinguished as follows: From *singularis* by (1) the tanylobous prostomium, (2) location of first dorsal pore on 10/11 (or even 9/10), (3) location of nephropores on or dorsal to *d*, (4) segmental location of the spermathecal pores, (5) saddle-shape of clitellum, (6) ornamentation of the penial setae, (7) location of genital markings in *aa*, (8) location of genital markings on intersegmental furrows, (9) presence of thick-walled accessory diverticulum on the spermathecal duct, (10) shape of spermathecal diverticulum, and possibly also by differences in setal formula. From *caroliniana* by (1) the tanylobous prostomium, (2) location of first dorsal pore, (3) saddle-shape of clitellum with posterior boundary at 18/19, (4) location of prostatic pores on *b* and slightly more lateral location of the seminal grooves, (5) presence of accessory chamber or diverticulum on spermathecal duct, (6) shape of spermathecal diverticulum, (7) definitely marked off, relatively

wider and shorter spermathecal ampulla, (8) circles of saw-tooth ornamentation on penial setae, and possibly also by a more anterior location of the male pores (vide Eisen, 1900, pl. xiii, fig. 137b). Original descriptions of both species (Eisen, 1899) are unavilable as also the types.

In view of the differences in method of preservation and in manner of description, the possibility of variations in connection with certain characteristics as well as of deformations that may affect recognition of characteristics of penial setae, determination of the taxonomic value of some of the apparent distinctions is at present difficult. Some of the differences listed would not be regarded as of taxonomic value in certain other Megascolecid genera. The distinctions are so numerous and so consistent on all of the material examined that it seems advisable at present to regard the Tennessee forms as specifically distinct from both *singularis* and *caroliniana*. Recharacterization of both species from properly preserved, sexual material from type localities is needed. There is also reason for suspecting that worms from Illinois and Indiana which have been identified as *singularis* differ from the types (or perhaps only from the original description) in ways that are more important than has been recognized (vide Eisen, 1900, and Heimburger, 1914).

Diagnosis.—Male pores slightly behind 18/19, in straight seminal grooves extending in a lateral portion of *ab* between setal arcs of xviii and xx, prostatic pores in *b* and just lateral to termini of seminal grooves. Sexthecal, spermathecal pores slightly behind 6/7–8/9, on or just lateral to *b*. Genital markings on 15/16–17/18, 20/21–24/25, paired or in transverse rows of 4, 3, or 2. Female pores anteromedian to *a*. Setae: $ab < cd$, $bc < aa$, $dd\ ca. = \frac{1}{2}$ C, ventral setae of vii–lx slightly enlarged but ornamented as on vi and x. Clitellum saddle-shaped, 12/13–18/19. First dorsal pore on (9/10) 10/11. Nephropores on or slightly dorsal to *d* but on ii at or just below levels of lateral furrows of the prostomium. Prostomium tanylobous. Pigmentation? Length 70–110 mm. Diameter 2–3½ mm.

Gizzards in v–vi; no calciferous glands or lamellae but papillose protuberances on inner wall of gut in x–xiii arranged in more or less regular longitudinal rows; intestine begins in xvii, typhlosole begins in xix–xx, of simple lamellar type. Dorsal blood vessel single, last hearts in xii. Spermathecal diverticulum lateromesially flattened, vertical, opening into duct entally just lateral to a hemispheroidal, thickwalled protuberance. Penial setae 1 mm. long, tips pointed, slightly flattened on two opposite sides, with a few circles of saw-tooth-like ornamentation.

Distribution.—The type locality is unknown but is somewhere in Tennessee.

REFERENCES

Eisen G. 1900. Researches in American Oligochaeta with especial reference to those of the Pacific coast and adjacent islands. Proc. California Ac. Sci. (3), Zool. 2.
Gates, G. E. 1929a. The earthworm fauna of the United States. Science, 70.
1929b. Earthworms of North America. J. Washington Ac. Sci., 19.
1937a. Notes on some species of *Drawida* and *Pheritima* with descriptions of three new species of *Pheretima*. Bull. Mus. Comp. Zool., Harvard, 80, (7).
1937b. The genus *Pheretima* in North America. Bull. Mus. Comp. Zool., Harvard, 80, (8).
1938. *Pheretima diffringens* (Baird) and other Asiatic *Pheretima*. Lingnan Sci. J., Canton, 17.
1942. Check list and bibliography of North American Earthworms. Am. Mid. Nat., 27, (1).
Hague, F. S. 1923. Studies on *Sparganophilus eiseni* Smith. Trans. Am. Mic. Soc., 42.
Michaelsen, W. 1900. Oligochaeta. In Schulze', Das Tierreich, 10. Berlin.
1909. The Oligochaeta of India, Nepal, Ceylon, Burma and the Andaman Islands. Mem. Indian Mus., Calcutta, 1.
Smith, F. E. 1924. The calciferous glands of *Lumbricidae* and *Diplocardia*. Illinois Biol. Mon., 9.
Stephenson, J. 1923. Oligochaeta. The Fauna of British India, Ceylon and Burma. London.
1930. The Oligochaeta. Oxford.
1933. Oligochaeta from Australia, North Carolina and other parts of the world. Proc. Zool Soc., London, 1932.

THE MECHANISM OF HEREDITY IN RELATION TO THE THEORY OF NATURAL SELECTION

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Darwin meant to deal with "hereditary modification" (?1912, p. 3) but he went on to include individual differences ("for they are often inherited," ibid., p. 38), which according to present information, are mostly noninheritable. Since these individual differences ("of the highest importance for us," ibid., p. 38) were postulated as the material upon which natural selection acts to produce organic modification, their prevailing noninheritance at once deals the theory a deadly blow.

As a practical consideration, vital to his theory, Darwin assumed that any variation may be inherited. In the field of individual variations, now called fluctuating variations, what is inherited is not particular variations but the tendency to vary more or less from the average racial standard. Fluctuating variations, the range of which remains about the same from generation to generation, reflect not exactness but rather the inexactness of heredity. Darwin evidently considered that all characters, all variations, of any organism are represented in its germplasm so that they may be inherited but this is now known not to be the case.

On this point D. H. Scott says, "The small variations which are so common, and on which the Darwinian tended to rely, as the material for natural selection to work on, have turned out for the most part to be mere fluctuations, oscillating about a mean, and therefore incapable of giving rise to any permanent new forms. Such fluctuating variations appear to depend on some action of the environment on the individual, and not to indicate differences in the germ-cells." (1924, pp. 10–11.)

Charles O. Whitman makes a far more sweeping statement contradicting the Darwinian view of heredity, saying: "There is really no transmission of characters anywhere in the organic world. . . . Parent and offspring are each independent developments, alike or different according as the germs from which they develop are alike or different, and according as the conditions of life are alike or different." (1919, p. 175).

THE CHARACTERS OF THE SOMA DO NOT AFFECT, AND MAY NOT REFLECT, THE CONSTITUTION OF THE GERM PLASM

When Darwin attempted to link the utility of a character with its inheritance, he was further misled. Among other ventures of this nature, he launched the following: "If variations useful to any organic being ever do occur, assuredly individuals thus characterized . . . from the strong principle of inheritance . . . will tend to produce offspring similarly characterized." (?1912, p. 115.) "variations, however slight . . . if they tend to be in any degree profitable . . . will generally be inherited by the offspring." (ibid., p. 55.)

Omitting comment on the question as to whether "variations, however slight" can be profitable, it should be pointed out that the "utility" of a character has no bearing on its hereditability. Inheritance depends upon the germ plasm while utility is an experience of the soma; there may be no connection. From this distinction ensue various considerations damaging to natural selection theory.

Without taking an extreme view as to the distinctness of somatic and germ cells (unwarranted, anyway, in the light of animal regeneration and vegetative propagation), it may be safely said, nevertheless, that in most organisms the germ plasm is a continuous stream from which the representatives of each generation derive, but upon which they do not have any effect, so far as known.

Walter notes that, "Darwin felt this difficulty and presented with apologies his provisional hypothesis of pangenesis . . . Pangenesis assumes that every bodily part sends contributions to the germ-cells in the form of 'gemmules.' Such gemmules . . . then reconstruct in the germ-cells the characters of the entire body, including acquired modifications as well as all others, and thus there is no theoretical reason why acquired characters cannot be transmitted. Unfortunately there is no tangible basis in fact for this delightfully simple explanation to rest upon. . . . Nothing we have subsequently learned of minute cell structure favors this hypothesis, while many facts go quite against it." (1930, p. 73.)

The great unanimity with which biologists have rejected the hypothesis of transmission of acquired characters (and none have been more emphatic than selectionists in this respect) is further evidence that knowledge of a mechanism for modification of the germ plasm by somatic influence is lacking.

The phenomenon of a *Begonia* leaf regenerating an entire plant, including flowers and seeds, has been urged against the theory of continuity of the germ plasm, but as bearing upon the present thesis this argument is harmless—on the contrary, indeed, it is beneficial. Vegetative propagation is the usual way of preserving uniformity in horticultural productions. Let seeds be matured and grown, however, and there occurs a flood of variation which demonstrates clearly that keeping the somatic characters to a certain standard for an indefinite period has not affected the germ cells in such a way as to make them reproduce those characters.

Maimed animals, shattered trees, leaving whole, not crippled, descendants, and moribund creatures making reproduction their last effort, prove that individuals, themselves defective, can produce normal offspring. These happenings indicate that it may make no difference whether or not there is "selection." The individual is merely the custodian and (except in a nutritive sense) not the maker of the germ plasm. It is the composition of the germ plasm that largely determines the character of the next generation. As the somatic traits of the parents (temporary harborers of the germ plasm) are not necessarily reproduced, a "selection" based on merit ("fitness") may have no influence on specific characteristics of descendants.

Morgan bluntly says "the character of the parents does not affect the properties of the germ-cells." (1932, p. 188.) Pearl may be quoted as follows: The "facts in general show that the somatic and the germinal conditions or states with reference to a particular character may be quite different in the same individual. It results, then, that the somatic condition of such a character in the progeny has no direct or necessary relation to the somatic condition of the same character in the parent. Nothing is brought out more clearly by all recent experimental studies of inheritance than that the somatic condition of a character in a particular organism is a very unreliable criterion of the probable condition of that character in the progeny of that organism. (1915, pp. 65–66.)

"Let us now turn to the consideration of our second rule, which must be fully enforced if natural selection is to be an important factor in the causation of evolutionary change. This, it will be recalled, was that the survivors must produce offspring which bear characters like those which had led to the survival. Or, to put the matter crudely, the survivors must transmit their characters to their offspring. In pre-Mendelian days this phase of the subject was always neatly and summarily disposed of by stating, as one of the *facts* on which the theory of natural selection rested, that 'variations are inherited' or 'like produces like.' Times have changed. We are a great deal less certain about that particular brand of inheritance which the theory of natural selection demands than we were before any one had taken the trouble to make experiments on heredity. The essential difficulty lies here. The differences upon which natural selection directly operates are

somatic differences, by hypothesis and in fact. Every worker in genetics has learned since the truly epoch-making researches of Johannsen to be extremely cautious in assuming *a priori* that any particular somatic difference is so inherited." (Pearl, 1917, pp. 71–72.)

"Expressed in Johnansen's words, the basis of the modern conception of heredity is: 'Personal qualities are the reactions of the gametes joining to form a zygote; but the nature of the gametes is not determined by the personal qualities of the parents or ancestors in question.'" (East, 1912, p. 644.)

A bar to the success of natural selection, unknown to Darwin, is the presence of recessive genes, not apparent in an individual, but which may crop out, even with lethal effect, in descendants. It is possible, therefore, that an individual, entirely fit, might be one whose survival would insure the termination, through lethal genes in its progeny, of that particular line of descent.

Shull notes that, "An important evolutionary consequence of this lack of correspondence between the characteristics of an animal or plant and its genes is that whatever relation exists between the organism and its environment need not exist between many of its descendants and the environment, even though the environment be wholly unchanged." (1936, pp. 118–119.) The consequences of this line of argument to a hypothesis like that of natural selection, which is wholly one of environmental influence, are anything but constructive.

THE CONSTITUTION OF THE GERM PLASM DOES NOT AFFECT, AND MAY NOT REFLECT, THE CHARACTERS OF THE SOMA

"To put this thought in other words," says W. D. Lang, "the morphic expression of the difference between two forms is by no means proportional to the fundamental or genetic difference." (1921, p. iv.)

These conclusions follow from the relations of soma and germ plasm stated in preceding pages and need be repeated only for the benefit of those who consider "possibilities infinitely wider than the actual," one of which is the environmental selection of genes.

The essential independence of soma from germ is asserted by Jennings in the following passage: "Since most mutations are recessive in their effects, and since only one gene of the pair of genes present is mutated, as a rule the mutation produces no manifest effect on the individual in which it occurs. The fact of its occurrence cannot be detected in that individual. It is only when, by the processes of mating in ordinary reproduction, two of the recessive mutations get together in the same pair, in some of the descendants of this individual, that the effect of the mutation appears to view. Thus when the mutation becomes manifest, it has actually occurred, as a rule, at least two generations earlier, in one of the ancestors of this individual." (1935, p. 344.) More recently, McClung has phrased it, "By some insulating device the germinal elements within the gonad do not participate in somatic processes, but merely perpetuate themselves." (1941, p. 266.)

CYTOPLASMIC INHERITANCE

There is some evidence of cytoplasmic, as contrasted to chromosomal, transmission of characters (for a review of the literature see Sirks, 1938) but this is no comfort for selectionists as it tends to show the possibility of the inheritance of acquired characters—a principle which, so far as it is effective, renders natural selection superfluous. A recent statement, however, minimizes the importance of this type of heredity, Dobzhansky, saying "judging from the present incomplete data, cytoplasmic inheritance is so rare relative to genic inheritance that in the general course of evolution the former can hardly play more than a very subordinate role." (1937, p. 72.)

CONCLUSIONS

Hereditary modifications are now called mutations. They originate in the germ plasm and, therefore, occur first in an individual that does not, in its own body, manifest the mutation. Under natural selection theory the individual will survive or not in accordance with the fitness of its "personal" or somatic characteristics. The constitution of its germ plasm can have nothing to do with its survival. Hence the fate of a mutation at the outset is decided by chance. As mutations are of rare occurrence and as they are chiefly injurious or even lethal in effect, the probability that they can be an important factor in progressive evolution under selection theory is slight.

This state of affairs is admitted by neo-darwinians but they attempt to save the situation as best they may by pointing out that mutant genes, which by chance enter into the germinal constitution of the race, "will get distributed to many individuals, the gene complexes of no two of which are alike." (Wheeler, 1936, p. 99.) The acceptability of natural selection doctrine is not improved by this argument. It is tacit in the expression quoted and apparent from the phenomena of fertilization that each individual of a sexually reproducing organism has an unique gene complex. If it become a parent it will contribute to other gene complexes, each unique. These combinations, a different one for each successful fertilization, may be and usually are numerous. The gene complexes of offspring then are many, each with different potentialities, but they derive from parents of only two somatic complexes. Again it is evident that there can be no exact correspondence of soma and germ, hence no effectual selection of gene-complexes on the basis of somatic characters. In sexual reproduction, under the present understanding of heredity, gene complexes, whether favorable or otherwise, can not be perpetuated. Their very nature implies unending change, and as those of descendants are not like those of ancestors there is no way in which selection can get an effective grip on the process.

Weismann, the ultra-selectionist, did Darwin little service by proving the essential independence of the germ plasm from the somatoplasm. Selection, if it exists at all, must be through the medium of the soma, thus cannot act directly on the germ plasm upon which continuity of the race depends. It would seem, therefore, that there is no mechanism that can make evolution by natural selection possible.

LITERATURE CITED

Darwin, Charles. 1912? The origin of species by means of natural selection or the preservation of favored races in the struggle for life. Reprint 6th Edit., xix+501 pp.
Dobzhansky, Theodosius. 1937. Genetics and the origin of species, xvi+364 pp., 22 figs., 22 tables.
East, E. M. 1912. The Mendelian notation as a description of physiological facts. Amer. Nat., 46 (551), pp. 633–655, 1 table.
Jennings, H. S. 1935. Genetics, xi+373 pp., 70 figs.
Lang, W. D. 1921. Catalogue of the fossil Bryzoa (Polyzoa) . . . British Museum, 3(1), cx+269 pp., 8 pls., 115 figs.
McClung, C. E. 1941. Evolution of the germ-plasm. Science, 93(2412), March 21, pp. 265–268.
Morgan, Thomas Hunt. 1932. The scientific basis of evolution, 266 pp., illus.
Pearl, Raymond. 1915. Modes of research in genetics, vii+182 pp., tables.
1917. The selection problem. Amer. Nat., 51(602), Feb., pp. 65–91.
Scott, D. H. 1924. Extinct plants and problems of evolution, xiv+240 pp., 163 figs.
Shull, A. Franklin. 1936. Evolution, x+312 pp., 64 figs.
Sirks, M. J. 1938. Plasmatic inheritance. Botanical Review, 4(3), March, pp. 113–131.
Walter, H. E. 1930. Genetics, an introduction to the study of heredity, 3rd Edit., xxi+35 pp., illus.
Wheeler, W. F. 1936. Inheritance and evolution, 116 pp., 32 figs., tables.
Whitman, Charles O. 1919. Orthogenetic evolution in pigeons, I, x+194 pp., 88 pls., 36 figs.

PETROLEUM IN SOUTHEASTERN OHIO

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Next to Pennsylvania, Southeastern Ohio is the oldest oil producing region in the United States. However, at no time in its history has it been a large producer, and for the past forty years production has been gradually declining. This paper considers only those areas which produce Pennsylvania grade oil. All oil produced from Washington, Carroll, Columbiana, Harrison, Jefferson, Belmont, Meigs, Monroe, Hocking, Perry, Noble, and Tuscarawas counties is Pennsylvania grade, except the oil from the Corning pool in Perry county. This grade of oil is also produced in parts of Athens, Fairfield, Vinton, and Muskingum counties. Washington and Monroe have been by far the largest producers.

The pools, while numerous, are mostly small and not more than two or three include ten square miles. From the beginning of exploration in 1860 to the present time between 65,000 and 70,000 wells have been drilled, giving a developed area of more than 300,000 acres. Condit (1916) estimates the wells drilled in the Woodsfield quadrangle alone number about 2,000. There are now approximately 12,800 producing wells averaging about one-fourth barrel per day. The wells vary in depth from twelve to 3,300 feet. A number of the shallow wells, especially those in the Cow Run sand, are long lived. Wells in southeastern Ohio have nearly all been small, and the records rarely show one having an initial production as high as 500 barrels per day, though as high as 2,400 barrels has been known (Bownocker, 1921). The Pennsylvania grade oil varies from 28 to 50 degrees Baume in density. The most common color of the oil is dark green, but in places it is a bright red and elsewhere black.

GEOLOGY

The Appalachian geosyncline is the major tectonic element which accounts for the presence of oil in southeastern Ohio. The western flank of the syncline underlies this portion of Ohio. The regional dip is, therefore, to the southeast at the rate of about 35 feet to the mile (Verwiebe, 1930). At least three prominent structural features modify this large basin. Most prominent of these is the Cambridge Arch, known as the Burning Springs-Volcano anticline in West Virginia, which crosses the Ohio River into southern Washington county and can be traced into central Noble, western Guernsey, and eastern Coshocton county where it dies out. Paralleling the Cambridge Arch on the west is the deep Parkersburg-Lorain syncline. It begins in southern Washington county, trends northwest through western Morgan, western Muskingum, central Coshocton, and on into central Holmes county. Minor structural elements such as domes, noses, ravines and terraces are present in considerable abundance.

Producing Horizons.—The number of producing horizons in southeastern Ohio suffers by comparison with the large number found in Pennsylvania. Nevertheless, 24 different sands have produced either oil or gas, and of these twelve are of importance. In making correlations in eastern Ohio the principal reference bench is the Pittsburgh or No. 8 coal which lies at the base of the Monongahela formation of the Pennsylvania system. It is the most prominent coal bed of the state, and is sufficiently near the surface to act as a guide of reference to the Penn-

[1]The writer wishes to acknowledge the aid and information given by Dr. Wilbur Stout, State Geologist, Geological Survey of Ohio.

sylvanian and Mississippian oil horizons. In descending order the major productive sands are: (Lockett, 1942)

Sand	Depth in Feet Below Pittsburgh	Sand	Depth in Feet Below Pittsburgh
First Cow Run	300	Maxton	950
Buell Run	350	Big Lime	975
Peeker or Second Cow Run	525	Keener	1,060
Macksburg	650	Big Injun	1,100
Salt Sand Group	750	Berea	1,600

The First Cow Run sand is the principal producer in the Cow Run, Newell's Run, and Moore's Junction pools. About one-third of the wells are dry holes, because of the erratic thickness and distribution of the sand (O'Rourke, 1942). The Macksburg sand is most important as a producer in the vicinity of Macksburg, but has produced some oil and gas in Noble, Athens, Meigs, Morgan and Monroe counties. It is patchy, rather coarse, and varies from 10 to 50 feet in thickness. The Second Cow Run sand has produced only in the area where it was first named in Washington county. The Salt sand was named because of the large amount of salt water commonly found in it. Scattered gas and oil wells produce from Meigs to Columbiana county. The Maxton sand is of somewhat greater importance, but because of its position at the base of the Pottsville is extremely erratic in its distribution.

The Big Lime of southeastern Ohio has produced considerable oil and gas in Belmont, Monroe, Athens, and Washington counties. The oil lies in thin layers of quartz sand which are interbedded with shaly limestone. The Keener sand lies below this limestone. It is an important producer of gas and oil in Monroe, Washington, Morgan, Athens, Noble, Guernsey, and Belmont counties. It is formed of alternating beds of fine and coarse grained sandstones, and in many places carries considerable brine. The average thickness is from 25 to 35 feet. This sand has been most important in the Graysville, Jackson Ridge, and Moose Ridge fields. The Big Injun sand is usually separated from the Keener by a few feet of shale. Sometimes they merge, and the entire sand is called the Big Injun. Only commercial production of oil and gas has been found in Washington and Monroe counties, and has been most important in the Sistersville field. The sand is coarse textured and contains some beds of conglomeratic nature. The thickness varies from 70 to 260 feet. It contains a great deal of brine, and many good Keener wells have been ruined by drilling into Injun water.

The most important horizon for oil and gas is the Berea, an exceptionally persistent sandstone which produces in every county in southeastern Ohio. Its thickness varies from 200 feet in the northern part of the area to as little as five feet, or even disappears in the southernmost sections. As a rule it is fine grained and light colored, but contains erratic lenses of coarser sand in which the oil and gas are found. In places it is interbedded with shales, and it may be represented only by sandy shales. Because of its widespread occurrence it has become the key horizon for sub surface mapping.

Relation of Production to Structure.—In southeastern Ohio, Cottingham (1927) states, three factors appear to govern the accumulation of oil: local structure, water content and energy of movement in the sand, and the porosity of the sand. The majority of the producing fields display some relationship to structure, although the relationship is rarely ideal. It has been estimated that 65 per cent of the shallow oil sand production, including the Berea, has some structural basis (Cottingham, 1927). Most of the crests of the anticlines or domes are devoid of oil. On the whole more oil has been found in the Berea on low noses, low on flanks of folds, or in shallow synclines, than on the crestal areas. Many of the Berea pools are at the upper end of structural embayments (Condit, 1912). Porosity alone can hardly account for this situation because it occurs too frequently with the

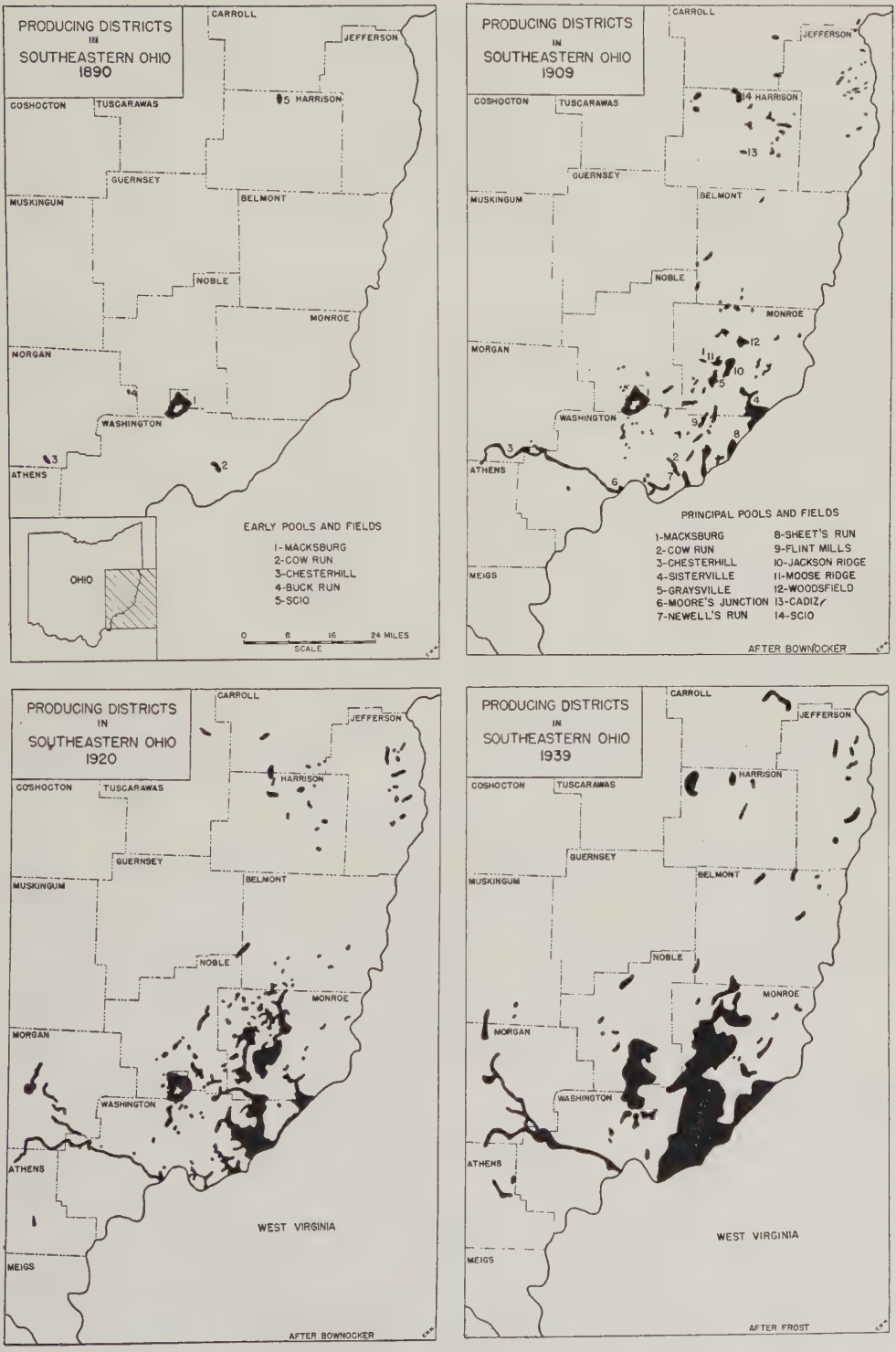

FIG. 1. The development of the Oil Region of Southeastern Ohio by periods.

same type of structure. Artesian conditions apparently prevail in the shallow sands, with the water movement being away from the hydraulic head along the Appalachian Plateau. Since the hydraulic gradient is low, and many sands are fine grained, the water movement is slow. It is possible that the disseminated oil was carried to the structural embayments and deposited because the velocity of the water movement is greatly reduced in these features (Rich, 1921). However, since so many pools are found where there are structural irregularities, it is safe to say that structure is the principal factor for the oil accumulations.

EARLY DEVELOPMENTS, 1814–1870

Oil from southeastern Ohio was known as early as 1814 when this substance was obtained as an impurity in the salt wells of Noble county. Occasionally, gas also escaped from such borings, and was looked upon with disfavor, because it was inflammable, and therefore dangerous. The first shipment of oil from this region occurred in 1843 when five barrels of "Seneca Oil" were shipped from Marietta to New York, by way of New Orleans. The oil was sold on arrival in New York to a drug house at 90 cents per gallon (Minshall, 1888). The principal use of petroleum at that time was medicinal, and from time to time small quantities were sold to drug companies. In 1852 a Pomeroy merchant made one of the largest shipments. One hundred barrels of oil were sent to St. Louis, and sold under the trade name of "Nerve and Bone" liniment (Bownocker, 1903). The first kerosene produced commercially in Ohio was distilled from Ohio shale near Buena Vista and from cannel coal from Flint Ridge, Warsaw and Canfield, about 1856–57. Twenty-five stills were in operation by 1860 and the business on a stable basis (Stout).

The finding of petroleum through drilling in Pennsylvania in 1859 prompted men in southeastern Ohio to investigate those areas where oil seeped from the earth, or gas issued from rock crevices. The first well was drilled in 1860 near a seepage on Duck Creek in Washington county. At a depth of 59 feet oil began to flow. Martin (1904) in his history of Ohio states, "In a few weeks the territory was full of prospectors and one could see derricks in every direction." Most of these shallow wells were producers, but excessive flows of water caused much trouble. In 1861 oil was discovered at Cow Run, and for a brief period this new area attracted the drillers. However, oil had been steadily declining in price, and since the only way to get it to market was to haul it by wagons over primitive roads to the Muskingum River, the profit of the individual producer was greatly reduced (Howe, 1891). Most of the shallow wells were short lived, and with the outbreak of the Civil War all efforts to develop the pools were abandoned.

The speculative flurry which swept the country at the close of the Civil War again directed attention to the oil possibilities of southeastern Ohio. Speculators from New England, New York, and Pennsylvania invaded the region for the purpose of leasing the land. Soon incorporated companies were formed with capital stock ranging from $100,000 to $1,000,000. Marietta alone had fourteen companies with a total capital stock of $8,300,000 (*Marietta Register*, March 4, 1897). At this time the greatest development occurred south of Macksburg when a 50-barrel well was drilled at a depth of only 500 feet. Drilling progressed rapidly for several weeks, but the production did not meet with expectations, and transportation was inadequate. With the passing of the period of inflation the price of oil soon dropped, and as a result of economic conditions most of the principal producers withdrew from the field. Thus, the speculative period passed with no real discovery of oil.

While these developments were going on at Macksburg, drilling was almost at a standstill at Cow Run. In the spring of 1866 a well was drilled which had an initial flow of 100 barrels per day. Here again was the great expectation, and

the usual excitement. Territory that was regarded as productive sold at exhorbitant rates. Chamberlin (*Oil News*, July 29, 1899) has described the development: "Excitement ran high. At one time there was a community of thousands at the Run and the hungry prospector had a hard time to find rations. I doubt if we shall ever see in this county (Washington) again such a jam of human beings and capital on so small a space of territory. . . . The derricks were so close together that it was difficult to drive a wagon through the valley." According to Minshall (1888) the production of the field from January, 1867, to August, 1868, was about 150,000 barrels. At first the oil was hauled to Marietta by wagons, but in 1868 the first pipe line in Ohio was laid from the field to Parkersburg, West Virginia, five and one-half miles away. Most of the wells drilled were small producers and short lived so that the production in 1869 had decreased to 89,000 barrels.

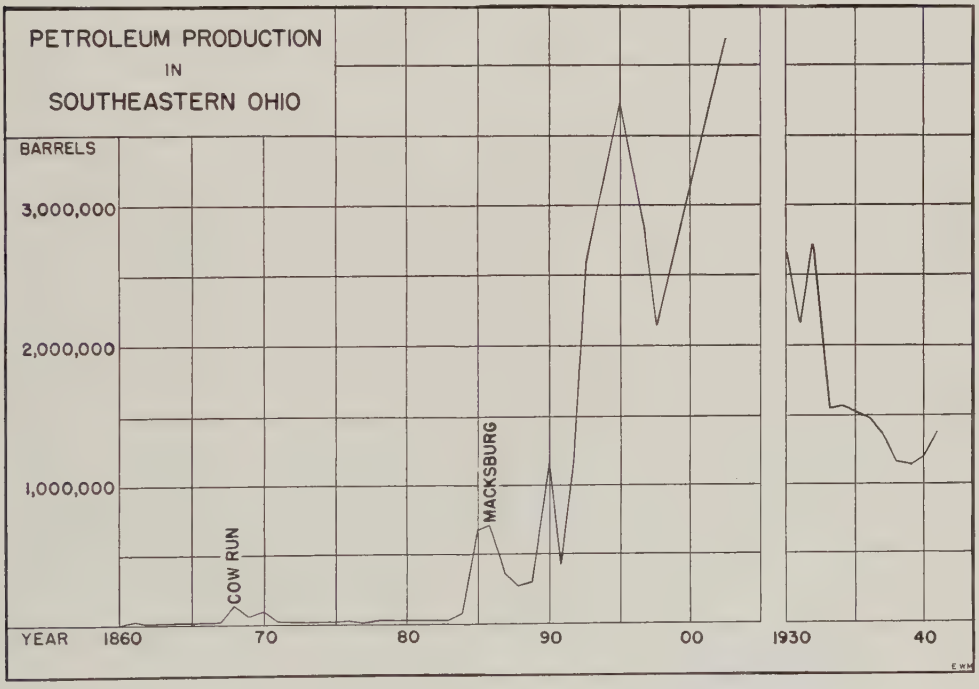

Fig. 2. Trend of petroleum production in Southeastern Ohio.

Little activity occurred until 1872 when a private producer started to survey the area around Macksburg. Minshall (1888) states, "The object of the survey seemed to be to start at Burning Springs and run a line through the producing districts of West Virginia and Ohio, taking the courses and distances of the producing wells, making a single map of the whole." During the survey a well was found that had been drilled in 1865 which was still pumping five barrels a day. After the well was cleaned out and torpedoed, production increased to 50 barrels per day. In the meantime the Cleveland and Marietta Railroad had been completed through Duck Creek Valley, making Macksburg a more desirable location for operations than it had been earlier. In 1874 one well yielded 150 barrels a day at a depth of only 150 feet. By 1877 thirty wells had been drilled in this vicinity (Lewis, 1928).

Most of the wells were either small or failures, and none went deeper than the Macksburg 500 foot sand. In 1877 a group of producers started to drill in search of the Berea sand, which was yielding oil in the White Oil district of West Virginia at a depth of about 1,400 feet. This first well in search of a deeper producing horizon reached the Berea at 1,427 feet, but it produced only brine and gas. This failure delayed the drilling of the second well until 1879, which flowed 15 barrels of oil per day, besides sufficient gas to pump the shallow wells. It was now proved that the Berea was productive in the area, but the production was too small to attract immediate attention.

MACKSBURG FIELD, 1879–1889

The development of the Macksburg field was retarded in the early 1880's by the country's financial depression which resulted in lowered oil prices, (*Marietta Times*, February 19, 1885), and by the unfavorable drilling conditions. The large body of salt water, between 900 and 1,100 feet, called for the latter amount of casing if the well was to be drilled to the Berea dry. So long as the production remained small, this added cost of casing acted as a prohibitive factor to any large scale development.

In 1883 a well was drilled on the upland which started at 100 barrels. This was the first of the large Berea producers, and at once led to extensive operations. The demonstration that oil existed beneath the hills, as well as in the valleys, greatly extended the possibilities of the field. In 1884 wells were drilled in rapid succession so that by January, 1885, more than 5,000 acres had been proved as productive territory. At that time there were 70 producing wells with a daily average of 700 barrels (*Marietta Times*, February 19, 1885). Drilling for the Berea also led to the development of the Macksburg 500 foot sand, and the Macksburg 140 foot sand. The production of the field increased rapidly as well after well was drilled. In August, 1884, it was 4,600 barrels; in December, 1884, 10,000 barrels; in March, 1885, 21,600 barrels; and in July, 1885, 79,700 barrels. From that time production decreased, the output having been 66,175 barrels in December, 1885, and 57,700 barrels in February, 1886 (Bownocker, 1903). For a yearly total the largest production occurred in 1886 when 703,945 barrels were produced.

There are no records as to the actual number of wells drilled, but the *Marietta Times* on February 5, 1885, reported, "About 100 new rigs are up in the Macksburg District for the purpose of putting down new wells," indicates that the number drilled must have been in the hundreds. The two largest wells drilled in 1885–86 are reported to have each started at 400 barrels, but the great body of Berea wells produced initially from 15 to 60 barrels per day. All contained sufficient gas to flow the oil, thus the operating costs were small.

One of the first problems with which the Macksburg producer had to contend was getting the oil to the market. The completion of a pipe line to the Cleveland and Marietta Railroad in the fall of 1883 gave temporary relief. A year later a pipe line was laid to the Muskingum River near Lowell, and the oil loaded on boats. Early in 1885 owing to cold weather the pipe lines were unable to carry the oil from the wells so that many tanks ran over, but it was considered a small loss because of the low price of oil (*Marietta Times*, February 5, 1885). In the summer of 1885 the National Transit, a subsidiary of the Standard Oil Company, laid a three-inch pipe line to Parkersburg, West Virginia. Shortly afterwards the National Transit bought the local pipe lines, and the transportation of the oil was from that time a comparatively easy problem.

As production increased at Macksburg, it became the Mecca of the oil fraternity. Hundreds of people poured into the area, largely from the Pennsylvania fields. The small country village of Macksburg grew into a city almost overnight. Hotels, saloons, drinking and gambling dens, brothels and boarding

houses were built by the score. With the population increasing so rapidly a food scarcity soon faced the inhabitants. Prices increased at tremendous rates. Many of the natives of Macksburg resented the influx of oil men with the resulting disorder. A number of ministers attempted to control the lawlessness, but before much could be accomplished production decreased, and the oil men began to direct their attention on new areas. By 1900 Macksburg was once again a small country community.

GREATEST REGIONAL DEVELOPMENT, 1890–1903

With the rapid decline of production in the Macksburg field, the drillers began to explore the adjoining regions. In 1890 a wild-cat well was drilled near Sistersville in Monroe county at a locality known as Pole-Cat. A vast reservoir of brine was found in the Big Injun sand, and the well considered worthless, and left standing for 18 months. In 1891 another well was drilled nearby and started to produce from 10 to 15 barrels daily. This was the first producer of the Sistersville field, and opened one of the largest oil districts in southeastern Ohio. As other wells followed, oil was secured in all, but with a flood of brine. In 1892 it was decided to pump the Pole-Cat well with the hope of reducing the salt water and thus securing oil. About 3,500 barrels of brine per day were pumped for weeks. Finally, it began showing oil and gas; this steadily increased until 500 to 600 barrels of oil per day were produced. Attention was now focused on the Sistersville field. Drilling progressed rapidly, and some of the wells made as much as 1,200 to 1,500 barrels daily (Bownocker, 1903).

By 1892 oil in southeastern Ohio had been found in a sufficient number of places to bring the entire region under consideration. In the next ten years thousands of exploratory wells were drilled. Every township had at least one wild-cat well. Since most of the drilling was carried out on unproven territory the percentages of failures were high. From 1891 to 1899, 2,450 recorded wells were drilled; of this number 860 were dry holes, or 34 per cent of the total. The greatest amount of drilling was centered in Washington and Monroe counties, but there was also considerable drilling in Harrison, Jefferson, Belmont, and Noble counties.

During this period 37 major pools were discovered. Production continued to rise from 1890 until 1903 when the peak was reached. In that year approximately 4,200,000 barrels of Pennsylvania grade oil were produced (Fig. 2).

Along with the drilling in new areas, the Macksburg field and a number of the older pools again attracted attention. Most of the wells drilled in the 1880's into the Berea were drilled wet. The object of the casing, which usually extended 65 feet below the Macksburg 140 foot sand, was merely to prevent caving, and not to exclude water. The salt water was kept from the oil horizon by placing a packer around the tubing a few feet above the sand. This could not be removed, since the salt water above would at once enter the sand and cause a deposit of paraffin around the hole. Thus, when sand obstructed the hole in the bottom of the tubing, or the pores of the rock became closed the production of the well ceased though the oil was not exhausted. Redrilling began about 1895. The new wells were drilled dry, and by 1903 most of the older productive territory had been reworked. The majority of the wells started from 4 to 50 barrels, while formerly their initial production ranged from 10 to 400 barrels (Bownocker, 1903).

While many pools caused local boom conditions during the 1890's, none attracted more attention than Scio in Harrison county. The search for oil in this area began in the early seventies, but drilling at that time was too shallow to reach the pay horizons. The discovery of oil near Jewett in 1895 appears to have encouraged a renewed interest in the vicinity of Scio. Progress was slow, but by 1898 the Scio Oil and Gas Company was organized with a capital stock of $10,000. However, the people had little faith in the company and the stock did not sell rapidly. Even after the first producer little attention was paid to the oil industry.

The first well drilled to the Berea began to produce June 7, 1898, at 18 barrels per day. The second well was also a small producer, and on its completion was not pumped for several days, at the end of which time it began to flow. As a result, the gas caught fire from the boiler and burned the derrick. This accident was widely publicized, and as usual the production exaggerated. This attracted the attention of the oil men, and started a boom which in a short time revolutionized the village.

At the time of the discovery of oil, Scio had a population of about 900, composed largely of farmers and merchants. It had long been the favored spot of Methodist ministers who had gone there because of the advantage the Scio College offered their children. Only once in 18 years had there been a saloon in the town

FIG. 3. Scio Oil Field during the Boom. (Courtesy of Ohio State Museum.)

and it was driven out by the angry citizens. The discovery of oil made a complete change in the appearance of the town. The population by January, 1899, was over 12,000.

"The village was unable to care properly for one-tenth of the people who had so suddenly gathered there. They lived in tents, shanties, reconstructed stables, boiler houses, or wherever they could find shelter. Many slept in chairs. Hundreds unable to find lodgings left on evening trains for nearby towns, returning the following morning" (Bownocker, 1903). There were eleven saloons in the town and an unknown number of "speakeasies." The barrooms and inns were a wild mass of teamsters, producers, workmen, speculators, mechanics, fakirs, gamblers, prostitutes, and hotel keepers all carrying on business and carousing. These features so horrified the staid citizens that many sold or rented their property and moved away.

Teamsters were in so great demand that frequently $40.00 a day was paid for their services. One operator reported having paid twenty dollars to have an ordinary boiler dragged sixty feet. The macadamized streets of the village were

soon cut through and converted into mere mud channels. As the town grew, the fire hazard became greater so that insurance rates for choice locations were frequently as high as $100 per month. With the coming of oil the college almost disappeared. In eight weeks' time the attendance dropped from 300 to about 25, and all departments of the school except two were moved to New Philadelphia.

The time of greatest excitement occurred in the early months of 1899, when there were 75 strings of tools at work. After that a rapid decline set in, so that by 1900 the population had dwindled to about 1,200. Nevertheless, the village did not recede to its former condition, for an enormous amount of money was left in the community.

FIG. 4. Bishop Oil Field, Woodsfield, Monroe County, 1900.
(Courtesy of Ohio State Museum.)

The total number of wells drilled was about 1,000. Of these perhaps 220 were within the corporation limits of Scio. Bownocker (1903) states that from a financial viewpoint the village wells were failures because of their close spacing. At the height of the boom about 5,000 barrels of oil were produced per day, but by 1901 this had decreased to 300 barrels. Today the field is still producing in very small quantities.

PERIOD OF DECLINE, 1903–1942

Since 1903 there have been no important discoveries of oil in southeastern Ohio. The drilling policy has been to extend the limits of the fields and to maintain as stabilized production as possible. Drilling, as previously, has been most active in Washington and Monroe counties. The possibility of securing a gas well along with a small amount of oil has been the principal incentive for drilling during the past two decades. Production has declined uniformly at the rate of two to four per cent each year; so that the 1941 production was 1,176,000 barrels.

Southeastern Ohio was the scene of one of the first attempts of producers to increase the rate of production by secondary recovery methods. In 1903 a pioneer producer in the Macksburg field began to repressure using gas. After applying pressure for ten days, it was released and the well produced at a great rate. This procedure became known as the Smith-Dunn process.

In 1911 repressuring was again tried near Chesterhill in Morgan county. About 150,000 cubic feet of air per day was forced into one well at a pressure of 40 pounds, and within a week the production of the surrounding wells had increased (Schaefer, 1941). After the initial success at Chesterhill, the process soon spread to other areas. Lewis in 1917 stated that about 4,000 wells were affected by repressuring on more than 90 leases. It is estimated that approximately 80 per cent of the early projects were successful, and records from 32 properties show an average increase of three and one-half times the production from time repressuring began (Schaefer, 1941). Gas was used when available, but more than 90 per cent of the repressuring units used air.

At the present time the largest repressuring project in Ohio is located in the Sistersville field. The productive area is now approximately 10,590 acres. The wells very early in the life of the field were placed on vaccum pump, and as larger and more pumps were installed the vacuum was increased in 1910 and 1916. Just prior to the introduction of pressure in 1933 the vacuum over the entire pool was 25 inches (Schaefer, 1941). Approximately 1,500 wells were completed in the pool since 1892. There was originally one well to 6.84 producing acres, but because of many abandonments there is now one well to 17.7 acres. To the time of repressuring the average production per well was 13,450 barrels and a recovery of 1,965 barrels of oil per acre. There are now 374 producing wells in the field. Five operators control the production, and all have agreed to repressure as a unit operation. Gas is injected in fourteen old wells and five new ones. Each well has its own pressure plant. Injection pressures vary from eight to ten inches vaccum in the center of the pool to 100 pounds pressure on the northwestern edge (Schaefer, 1941). The average daily intake volume is from 100,000 to 150,000 cubic feet. In the beginning about ten million cubic feet of outside gas was used to establish the cycle. At present about three million cubic feet of gas is pumped daily, of which 1,600,000 cubic feet is returned to the sand. At the start of the gas injection in June, 1933, the average daily production of the pool was 124 barrels per day. This slowly increased and reached a peak of 337 barrels per day in March, 1939, a gain of about 172 per cent. Since that time a slow decline has set in.

At present there are eight repressuring projects in Washington, Morgan, and Monroe counties. The shallowness of the producing sands, the close spacing of the wells, and the low injection pressure required are the chief factors that favor repressuring. The greatest disadvantages are the lack of preliminary work done to determine the exact nature of the horizontal and vertical changes in porosity and permeability of the sand reservoir. There is also some difficulty in the by-passing of gas from the injection wells to the producing wells so that in certain cases the gas does not move through those areas that are still saturated with oil.

The possibility of water flooding as a means of secondary recovery has been considered in southeastern Ohio. The Berea formation has been successfully flooded in northeastern Ohio in Medina county. The Big Injun and Cow Run formations have high permeability and could be flooded. The greatest disadvantage to water flooding is that the average recovery per acre of petroleum in southeastern Ohio has been low. Therefore, water flooding recovery methods using new drilling would not be economically applicable in many places (O'Rourke, 1940). Financial success of flooding will depend largely on acquiring leases at a reasonable price that have had a satisfactory natural production. It has been

estimated that with a spacing of one well to four acres, which will permit five rows of five inputs and four rows of four producers in each quarter-section, the cost of flooding will be (O'Rourke, 1940):

Depth	Cost per Acre
450 feet	$ 650.00
700 feet	1,100.00
1,200 feet	1,600.00
1,500 feet	2,000.00

One of the first horizontal wells in the world was drilled in southeastern Ohio. The process of horizontal drilling requires the sinking of a shaft to the oil sand and then drilling horizontally into the sand. Ranney (1941), the inventor of the process of horizontal drilling, states, "In the Ohio experiment six wells were drilled horizontally from a shaft in the First Cow Run sandstone. These three-inch wells were drilled in opposite pairs, half of them to property lines. While a 50-foot core was being pulled from one well, the drill rods (and duplicate tools) were being run into the opposite well. This was accomplished by a new machine, known as a 'rod puller,' which moves the rods at the rate of 100 feet per minute. The drill rods, in ten-foot lengths, were not disconnected until both wells were completed. In deep holes this cuts drilling time at least 75 per cent."

Horizontal drilling has a number of advantages over the usual method. It conserves steel, for horizontal wells require neither derricks, casing, nor tubing. The drilling of this type of well requires less than one-tenth of the power for the same length of sand exposed by vertical operations, and each shaft operating upwards of 400 acres exposes some 50,000 feet of producing oil sand. The greatest disadvantage to the extensive use of this method in Ohio is the initial cost. The total cost of shaft, equipment and two wells is about $75,000. At the present time the production from the Ohio horizontal well is about 2,000 barrels per year.

PRESENT CONDITIONS

The oil industry of southeastern Ohio has been suffering from depressed conditions for more than two decades. In 1939 the *Oil Weekly* reported that Ohio had the least return per dollar spent of all petroleum producing states. If both oil and gas were included for that year, there would have been a 75-cent return for each dollar spent. It is difficult to present actual costs of producing a barrel of oil in this section because of a lack of records for most leases, and in many instances producers' records are not kept under the desired classifications. The most recent attempt to consider production costs was made in 1941 when the Pennsylvania Grade Crude Oil Association prepared a brief for the Office of Price Administration. In order to obtain costs for the district, the most accurate method seemed to be to obtain from the producer the total "out-of-pocket" expense paid in connection with the given production. From the producer's total expense any amount paid for new drilling, new equipment of a capital nature, and interest on borrowed money were eliminated. A reasonable amount to represent compensation for personal services was included. To this was added the cost of depletion, depreciation, amortization, gas sales, and interest on investments as given for the past eight years by the Petroleum Administrative Board and the United States Tariff Commission. The total was then considered to be the total of the producer's operating and general overhead expense.

The data gathered covered eleven properties on which are located 1,630 wells. The total production of the wells was 147,534 barrels, which was thirteen per cent of the total for southeastern Ohio. It was found that it cost $2.70 for each barrel of oil produced in 1940. The costs were divided in the following manner: depletion, 14 cents; depreciation, 35 cents; amortization of intangible development costs, 27 cents; general expenditures, $1.83; interest, 30 cents; less 19 cents for

the sale of gas. In 1940 the average price paid for the Pennsylvania grade crude of Ohio was $1.87. This crude was sold at a loss because it had to compete with areas of lower cost production.

Table I is a summary of production costs which shows the percentage of Pennsylvania grade oil that can be produced at or below 1940 costs in each of the producing states, i.e., Pennsylvania, New York, West Virginia, and Ohio. A special study was also completed by the Pennsylvania Grade Crude Oil Association

TABLE I

PERCENTAGE OF PENNSYLVANIA GRADE OIL PRODUCED BY STATES, AT OR BELOW COST SPECIFIED FOR THE YEAR 1940

	Pennsylvania	New York	West Virginia	Southeastern Ohio
Less than .40 per barrel	.....	.....	.....	.....
Less than .80 per barrel	.....	.....	.....	.....
Less than 1.20 per barrel	.....	.....	.....	.....
Less than 1.60 per barrel	9.87	.....	.....	.....
Less than 2.00 per barrel	43.04	.....	3.88	.....
Less than 2.40 per barrel	53.69	38.00	8.12	49.10
Less than 2.80 per barrel	64.90	46.00	10.92	51.62
Less than 3.00 per barrel	79.77	59.00	58.30	55.16
Less than 3.20 per barrel	90.87	86.50	64.22	100.00
Less than 3.40 per barrel	94.31	92.30	97.37	.....
Less than 3.60 per barrel	97.86	94.70	98.23	.....
Less than 3.80 per barrel	98.41	96.00	98.63	.....
Less than 4.00 per barrel	99.00	96.70	98.95	.....
Less than 4.20 per barrel	99.06	97.00	98.95	.....
Less than 4.40 per barrel	99.42	97.30	100.00	.....
$4.40 and over per barrel	.58	2.70	.....	.....

TABLE II

	Crude Market 1941	Production Barrels per Year—1940	Per Cent and Barrels Which Can be Produced Without Loss Under Present Crude Market	
			Per Cent	Barrels
New York (Allegheny)	$2.75	3,462,120	45	1,557,954
Bradford	2.75	14,285,000	76	10,856,600
Kane to Butler	2.68	3,713,000	15	690,717
Pennsylvania (Comp.)	2.73*	.....	63	.....
West Virginia	2.34	3,400,000	4	137,760
Southeastern Ohio	2.30	1,176,000	24	282,240
		26,036,120	52	13,525,271

*Weighted price.

to determine the percentage of crude that could be produced profitably from each of the districts at the market price of August 23, 1941. This was done by direct calculation of the costs for producing a barrel of crude oil. These percentages together with the market price of crude, the yearly production for each district for 1940, and the barrels of crude that can be produced without loss under the stated market price are shown in Table II. Multiplying the production of each

district by the percentage which can be produced at a profit gives the number of barrels that can be produced without loss. This shows that of the 1,176,000 barrels produced in southeastern Ohio in 1940 only 283,240 barrels, or 24 per cent, were marketed profitably.

However, it can be expected that this region will continue to produce at a gradually decreasing rate for many years. In 1941 the American Petroleum Institute estimated the Pennsylvania grade oil reserve of Ohio at 595,000,000 barrels. Of this amount 30,284,000 barrels are recoverable under present methods. Little or no allowance was made for secondary recovery methods; so it can be reasonably assumed that the actual recoverable reserve is twice the above figure, or 60,000,000 barrels. At the present rate of production this is approximately a 50-year reserve.

In spite of the fairly large recoverable reserve, the low price of oil has resulted in many abandonments, as illustrated by the following chart:

Year	Production	New Wells	Abandonments	Average Crude Prices
1938	1,161,000	72	1,105	$1.40
1939	1,160,000	70	823	1.60
1940	1,176,000	112	739	1.87
9 months 1941		121		

At the present time the junk value of wells is $800 to $1,000 and the need for steel will doubtless stimulate this trade unless a higher price for oil is obtained. Many producers find it preferable to salvage material and obtain cash rather than to continue production.

The increased demand, created by the present war needs, has stimulated new developments slightly. Production in 1941 increased approximately 500 barrels a day over that of 1940, and could be further increased. There was considerable development in older areas and wild-catting for new pools resulted in the discovery of the Clayton Perry Pool in Clayton township, Perry county. Its area is about 2,000 acres and is now producing at the rate of 1,400 barrels per day with an estimated total recovery of 3,000,000 barrels. Its area has not been completely defined, nor, due to the 3,200 foot depth and corresponding drilling costs, will there be substantial further development under conditions as they exist today. There are a number of areas which will be prospected for new pools with a rise in the market price, some cleaning out of old wells will be done, some new secondary recovery projects will help maintain or increase production, but for the immediate future the main increase in production will come from new areas and further development of the Clayton Perry Pool.

BIBLIOGRAPHY

1. **Andrews, M. R.** *History of Marietta and Washington County*, pp. 415–423. Biographical Pub. Co., Chicago, 1902.
2. **Bownocker, J. A.** *Oil and Gas*, Ohio Geological Survey, Fourth Series, Bull. 1, pp. 126–320, 1903.
3. ———. Rise and Decline in Production of Petroleum in Ohio and Indiana, Trans. Amer. Inst. Min. Met. Eng., 65: 1–12, Feb., 1920.
4. **Condit, D. D.** Structure of the Berea Oil Sand in the Woodsfield Quadrangle, Belmont, Monroe, Noble and Guernsey Counties, Ohio, U. S. Geological Survey, Bull. 626: 233–249, 1916.
5. ———. Oil and Gas in the Northern Part of the Cadiz Quadrangle, U. S. Geological Survey, Bull. 541: 9–17, 1912.
6. **Cottingham, K.** Structural Conditions in Portions of Eastern Ohio, Amer. Asst. Pet. Geol., 11: 945–958, 1927.
7. ———. Oil and Gas Developments in Ohio in 1940, A. I. M. E., Pet. Div., pp. 372–374, 1941.
8. **Hildreth, S. P.** *First Annual Report of the Geological Survey of Ohio*, pp. 62–63, 1838.

9. **Howe, Henry.** *Historical Collection of Ohio*, 2: 629–631. H. Howe and Co., Columbus, 1889–91.
10. **Lewis, T. W.** *Southern Ohio and the Muskingum Valley*, 1: 145–149, 253–259; 2: 93–99, 383–389, S. J. Clarke Pub. Co., Chicago, 1928.
11. **Lockett, J. R.** General Structure of the Producing Sands in Eastern Ohio in *Structure of Typical American Oil Fields*, (Amer. Asst. Pet. Geol.), 1: 138–147, 1929.
12. ———. An Outline Description of Producing Horizons in Eastern Ohio, (mimeographed pamphlet), 1942.
13. **Martin, F. M.** *State Centennial History of Ohio and Noble County*, pp. 114–120, S. A. Bryant Pub. Co., Madison, Wis., 1904.
14. **Minshall, F. W.** History and Development of the Macksburg Oil Field, Geological Survey of Ohio, Economic Geology, 6: 443–475, 1888.
15. **O'Rourke, E. V.** Lensing Sands of Ohio in *Stratigraphic Type Oil Fields*, (Amer. Asst. Pet. Geol.), pp. 382–385, 1941.
16. ———. Flooding in Ohio—Sand Characteristics—Well Spacing, Producers Monthly, 4: 22–23, June, 1940.
17. **Ranney, Leo.** Horizontal Wells are All in the Pay—and Flow by Gravity, Illinois-Indiana Petroleum Association, Ninth Annual Petroleum Conference, 1941.
18. **Rich, J. H.** Moving Underground Waters as a Primary Cause of the Migration and Accumulation of Oil and Gas, Econ. Geol., 16: 347–371, 1921.
19. **Schaefer, J. E.** Secondary Recovery in Ohio, Producers Monthly, 6: 11–15, April, 1941.
20. ———. Oil and Gas Development in Ohio in 1939, A. I. M. E., Pet. Div., pp. 353–357, 1940.
21. ———. Secondary Recovery Vital in Ohio Fields Operation, Oil and Gas Jour., 40: 59–60, April 24, 1941.
22. **Stout, Wilber.** An Historical Document of Interest to Petroleum Geologists, Amer. Asst. Pet. Geol., 22: 1687–1691, 1938.
23. **Summers, T. J.** *History of Marietta*, pp. 284–290, Leader Pub. Co., Marietta, 1903.
24. **Van Tassel, C. S.** *Book of Ohio*, pp. 710–727, Van Tassel Pub., Bowling Green, 1901.
25. **Verwiebe, W. A.** *Oil Fields in the United States*, pp. 65–81, McGraw-Hill Co., New York, 1930.
26. **Ohio**—Annual Review, Oil and Gas Jour., 39: 160, Jan. 30, 1941.
27. A Comprehensive Survey of Ways and Means of Increasing Crude Oil Production in Region No. 1, Producers Monthly, 6: 32–35, May, 1942.
28. Brief Presented by Pennsylvania Grade Industry at Hearings Before Office of Price Administrator, Producers Monthly, 6: 11–14, 34–37, Nov., 1941.

Bird Study and Ornithologists

Florence Page Jacques and her husband have here collaborated in producing a book that will be of considerable interest not only to ornithologists and experienced bird students, but to anyone who has ever thought of becoming interested in birds. The book deals principally with the author's relations to birds, bird trips, and ornithologists.

The author's experiences with bird study began with her marriage to Francis Lee Jaques, one of the foremost bird artists in the country and a member of the staff of the American Museum of Natural History. Her trips with her husband have taken her over much of this country (the back country of Minnesota, the waterfowl flyway down the Mississippi valley, the Appalachians and the Rockies) and parts of other countries (the Gaspe, England, Switzerland, and Panama), and behind the scenes at the American Museum of Natural History.

The author's general reaction to the field of bird study is summed up in her Preface: "When I first entered, I was entertained rather than sympathetic . . . but as I joined their activities my amusement changed to interest and then to joy. . . . This world is open to anyone, not merely those who have an innate love of birds. My knowledge has come slowly and even now my observation is far more joyful than scientific. But the deepening of insight and gradual knowledge has added infinitely to the richness of life." Reading the book, one feels with the author an increasing enthusiasm for the study of birds.

To the reader who knows the outstanding ornithologists of the country by name only, this book will give an intimate insight into their personalities. This reviewer will agree that these people are "some of the finest, the most delightful and inspiring people that I have had the good luck to know."

The colorful accounts of the author's trips and experiences, and the many excellent illustrations make this a very readable book, and one which will give some readers a new insight into the very interesting field of bird study.—*D. J. Borror.*

Birds Across the Sky, by Florence Page Jaques, with illustrations by Francis Lee Jaques. 1942. xii×240 pp. New York, Harper & Brothers. $2.50.

COMPOSITION OF FUNGUS HYPHAE IV: PHYTOPHTHORA[1]

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The genus *Phytophthora* was established by de Bary (2). De Bary realized that there was a close relationship between the genera *Phytophthora* and *Pythium*, yet he considered that the difference in the germination of the sporangia of the species, known at that time, justified the separation.

In the germination of *Pythium*, it was observed that the contents of a sporangium first passed into a thin-walled vescicle, which later burst, freeing the spores. This was thought to be a specific characteristic of *Pythium*. As new species of *Phytophthora* were discovered, it soon became apparent that some of them displayed similar sporangial germination. Thus, the real differences between the two genera in morphology and cytology have become meager.

More recently, Fitzpatrick (3) has stated that there is no adequate reason for distinguishing *Phytophthora* from *Pythium* and that, in time, the two genera may be merged under the older name, *Pythium*, unless a more valid basis of differentiation can be established.

After the writer had completed a study of the composition of the hyphae of representative species of *Pythium* (8), attention was next directed to a similar investigation of a number of species which have been assigned to the genus *Phytophthora*. It was thought that such a comparative study might furnish further evidence either for merging *Phytophthora* and *Pythium* into one group, as suggested by Fitzpatrick, or for continuing them as two distinct genera of Phycomycetes.

In Dastur's (1) description of the species *Phy. parasitica*, an account of the composition of the mycelium is also included. He reports the presence of pectic-like material and cellulose. Tests for callose were negative, and chitin was not detected. Methods employed and viewpoints of analysis were considerably different 30 years ago from what they are now. In endeavoring to compare the reports of Dastur on *Phytophthora* with the more recent analysis of *Pythium*, by the writer, no adequate idea of similarities or differences of the two genera, can be obtained.

SPECIES INVESTIGATED

For the purpose of this investigation, the following species of *Phytophthora* were secured: *Phy. cactorum* (Leb. & Cohn) Schröt., *Phy. parasitica* Dastur, *Phy. infestans* (Mont.) de Bary, *Phy. capsici* Leon., *Phy. hydrophyla* Curzi, *Phy. pini* Leon., *Phy. cinnamoni* Rand, *Phy. melongenea* Swada, and *Phy. citrophthora* (Smith & Smith) Leon.

PLAN OF STUDY AND RESULTS

The species of Phytophthora used in this study, with the exception of *Phy. infestans*, grew well in potato broth. For this species, lima bean broth was substituted. In contrast to the *Pythiums*, the *Phytophthoras* made much slower growth. All of them formed mats more or less compactly interwoven, except *Phy. cinnamoni*, which developed a discrete colony type of growth without much interlacing. These colonies were fragile and could be broken apart readily. The

[1]Approved for publication by the Director of the Ohio Agricultural Experiment Station.

same type of growth was displayed by *Phy. melongenea* during the first two or three weeks. Later the colonies grew together, forming a mat.

The same plan of analysis which had been found to be useful in determining the composition of other groups of fungi (6, 7, 8) was followed. Microchemical tests were used to direct the course of macrochemical procedure. Only qualitative methods were considered, and attention was directed entirely to the mycelium.

Some of the species of *Phytophthora* produced spores in potato broth; while others did not. Cultures varying in age from one week to three months were included in the study.

No difference could be detected between young and old cultures when the mycelia were observed in water mount in polarized light. Young cultures, three to four days old, and old cultures, three to four months old, were very dimly anisotropic, a condition which indicated the presence of callose or cellulose. When the hyphae were treated with a weak aqueous solution of ruthenium oxychloride, the dye was retained and could not be removed by prolonged washing in water. This characteristic of the mycelium, together with the absence of double refraction in polarized light, indicated the presence of pectic material on the outside.

Hyphae treated with Lugol's iodine solution followed by 70 per cent H_2SO_4 developed a blue color, which revealed the presence of cellulose. The presence of cellulose was confirmed with the aid of other cellulose reagents, such as $CaCl_2$-iodine, H_3PO_4-iodine, and LiCl-iodine (4). With some species of *Phytophthora* the blue color developed by the cellulose reagents appeared quickly; while in others the reaction was slow. In no case with fresh hyphae was there any swelling of the cellulose layer.

Information gained in these preliminary tests served as a guide for the procedure of analysis which was later formulated. It consisted in resolving the hyphae into component parts and identifying them.

Several fungus mats were cut into strips three to four millimeters wide, washed thoroughly to remove culture solution, then extracted for one hour in hot 0.5 per cent ammonium oxalate. The liquid was filtered off, and an equal volume of 95 per cent alcohol added. A finely divided precipitate appeared, which after a time settled to the bottom of the flask. A second extraction removed a smaller amount of material and a third none. The precipitates from the ammonium oxalate extractions were collected on a fritted glass filter, washed with alcohol, then taken up in a small quantity of water. When the Molisch test was made, a violet color appeared, indicating that a condensation product between alpha-naphthol and furfural was formed. A faint pink to brownish color developed when the orcinol-HCl reaction was applied. When a drop of $FeCl_3$ solution was added, a brilliant green color promptly resulted. The green color could be entirely removed by shaking with amylic alcohol. Pectic compounds could not be demonstrated as pectic acid by the addition of concentrated HCl or as calcium pectate with $CaCl_2$. When hydrolyzed with H_2SO_4 the product reduced Fehling's solution. The material removed with the ammonium oxalate extraction was not pectic compounds but was probably a mixture of pentose and hexose anhydride, as indicated by the orcinol HCl-$FeCl_3$ reaction.

With the outside covering removed, the mycelium did not permanently retain the ruthenium oxychloride dye, but it did stain with methylene blue. Extraction was next made with ammoniacal cupric hydrate sufficiently strong to dissolve cellulose promptly. When the liquid was filtered off and neutralized with HCl, a copious precipitate appeared. This was found to be isotropic when examined in polarized light, yet it gave a positive reaction when tested with cellulose reagents.

Further extraction with ammoniacal cupric hydrate removed nothing. The mycelium was still dimly anisotropic as at first and did not fix dyes. This inert character of the hyphae was suspected to be due to the presence of fatty acids.

Refluxing in 2 per cent alcoholic potash saponified the fatty acids in the outer portion of the hyphae with a result that the blue color appeared more quickly when the cellulose reagents were applied, and when the mycelium was again extracted with the cellulose solvent more material went into solution. It was necessary to repeat the process of saponification of fatty acids followed by extraction with ammoniacal cupric hydrate at least once, and in some instances, twice, before all the cellulose was removed. All the cellulose of *Phy. cinnamoni* could be removed without saponification of fatty acids.

The cellulose precipitates were collected on a glass filter, thoroughly washed, dried, and then suspended in 10 cc. of 17.5 per cent NaOH. The hydrate was allowed to act for 30 minutes with occasional stirring. The solution was then diluted with an equal volume of water and filtered through a glass filter. Part of the cellulose dissolved in the alkali and part did not. The residue was washed with 20 cc. of 8 per cent NaOH, then with water, followed with 1 per cent acetic acid, and finally with water until all free acid was removed. The portion which did not dissolve was found to be doubly refractive in polarized light, whereas the portion which was recovered from the extract by neutralizing the alkali was not doubly refractive. Both precipitates readily gave a blue color with cellulose reagents, and upon hydrolysis yielded reducing sugars. Tests for proteins were negative. It was concluded that two forms of cellulose were present: the alpha (5) form, which did not dissolve in the alkali, and another form, which did dissolve and could be recovered.

At this stage of the analysis, the walls of the hyphae were still intact. When viewed in polarized light they were isotropic, developed a brown color with cellulose reagents, and did not fix aniline dyes. The residue was proved to be chitin by a positive chitosan reaction. No callose or structural proteins were detected.

COMPARISON OF MYCELIUM OF PHYTOPHTHORA AND PYTHIUM

Very young *Pythium* hyphae are isotropic when observed with a polarizing microscope. This condition is due to a layer of pectic compounds on the outside. When this layer is removed, the anisotropic cellulose becomes visible. The pectic material is used up and disappears after five to seven days as the hyphae reach maturity, leaving the cellulose the outside layer.

Phytophthora hyphae present a dimly anisotropic appearance at all stages of growth. There is no true pectic layer on the outside. When the covering is removed, the mycelium presents the same appearance as at first, and at no time can the cellulose be made brightly anisotropic, Furthermore, two forms of cellulose were detected in *Phytophthora*.

In view of the biochemical differences which exist between these two supposedly closely related genera of fungi, it becomes evident that in the location of a new species, consideration might properly be given to the structure of the hypha to determine whether it conforms to the general pattern of the genus to which the species appears to belong. Previous studies by the writer have shown that there is a close conformity in mycelial structure among species of a genus.

SUMMARY

An investigation of nine different species of *Phytophthora* has been made in order to determine the composition and structural pattern of the mycelium. A basic skeleton of chitin was found to have superimposed upon it a mixture of two forms of cellulose, one of which was doubly refractive in polarized light and the other was not. These were impregnated with fatty acids. It was necessary to saponify the fatty acids with alcoholic potash before the cellulose could be removed by solution in ammoniacal cupric hydrate.

The outside layer was found to be a carbohydrate mixture which gave the

orcinol-HCl test for pentoses. The presence of a hexose was also indicated. No pectic compounds were present.

When viewed in polarized light, the same appearance is presented by young and old cultures of typical species of *Phytophthora*. In this respect there is a marked contrast between the two groups of fungi, *Phytophthora* and *Pythium*.

REFERENCES

(1) **Dastur, J. F.** 1913. On *Phytophthora parasitica*, nov. spec. A new disease of the castor oil plant. Mem. Dept. Agric. India. Botanical Series 5: 177–231.
(2) **de Bary, Anton.** 1860. Sur la formation de zoospores chez quelques champignons. Ann. Sci. Nat. (4 ser.) 13: 236–251.
(3) **Fitzpatrick, Harry M.** 1930. The lower fungus Phytomycetes. 331 pp. First edition. McGraw-Hill Book Company.
(4) **Post, E. E., and J. D. Laudermilk.** 1942. A new microchemical reaction for cellulose. Stain Technol. 17: 21–24.
(5) **Schorger, A.** 1926. The chemistry of cellulose and wood. pp. 596. First edition. McGraw-Hill Book Company.
(6) **Thomas, R. C.** 1928. Composition of fungus hyphae I: The Fusaria. Amer. Jour. Bot. 15: 537–547.
(7) ———. 1930. Composition of fungus hyphae II: Sclerotinia. Amer. Jour. Bot. 17: 779–788.
(8) ———. 1942. Composition of fungus hyphae III: The Pythiaceae. Ohio Jour. Sci. 42: 60–62.

Plant Communities of the Welaka Area, Florida

This bulletin contains detailed descriptions of twenty-four plant communities which occur in the Welaka area, Putnam County, Florida, the 2,180 acre tract comprising University of Florida's Conservation Reserve. The communities are classified by the author into seven types, and are carefully described on the basis of aspect, floristic composition, structure and extent. The association described include every primary type in the area, and the communities occupying abandoned fire lanes, lawns, ditches and roads are also discussed. An attempt has been made to analyze the successional relationships and some correlation with eight soil types is recognized. Climatic data are given but were not obtained in the plant habitats of the problem area. A list of 750 species of plants growing in the area make up twenty-eight tables, in which the abundance or rank of each species for each community is indicated, and vegetation maps and twenty-eight photographs are included.—*J. N. Wolfe.*

The Plant Communities of the Welaka Area. A. M. Laessle. 143 pp. Univ. of Fla. Publication, Biological Science Series. Vol. IV, No. 1. July, 1942. $1.50.

Physics and Philosophy

Readers familiar with the recent development of theoretical physics, in particular with relativity and quantum theory, will enjoy this book very much as a colorful supplement to their dry formulas and equally dry experiments. It remains doubtful, however, whether the sparkling style, the many striking similes and puns will satisfy those readers who look for information concerning the philosophical problems of our sources of knowledge, determinism versus free will, space and time, etc., in their relation to modern physics. Jeans' representation remains too much on the surface as to seriously touch the problems of present day philosophy, although his criticism of medieaval and antique philosophers and their verbal struggles is very striking. One cannot refrain from the observation that being a great physicist does not imply being a good philosopher, too. Nevertheless it is always instructive and entertaining to read what an original thinker has to say about any subject matter whatsoever, even if his exposition is only "popular" in the best sense of the word.—*Alfred Landé.*

Physics and Philosophy, by Sir James Jeans. 222 pp. Macmillan Company, New York, 1943. $2.75.

SOME INVESTIGATIONS OF THE WATER RELATIONS OF LICHENS[1]

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At intervals during the summers of 1941 and 1942 the writers collected samples of lichens at various times of day from a southwest facing sandstone cliff in Hocking County, Ohio, and measured the water content. The purpose of these periodic measurements was to find out when water absorption occurred, where the water came from, and when it was lost. Concurrent measurements of the humidity of the air adjacent to the plants and of the temperature of the air and plants were made with a view toward possible correlation of these data with the moisture data.

FIG. 1. *Gyrophora dillenii* (right center) and *Umbilicaria pustulata* (left center), about one-half natural size.

The lichens chosen for investigation were *Gyrophora dillenii* (Tuck.) Mull. Arg. and *Umbilicaria pustulata* (L.) Hoffm. (Fig. 1). These lichens occur together on the Blackhand sandstone cliff walls of Neotoma, a tributary valley of Clear Creek, Hocking County, in sufficient numbers to permit such an investigation. Gyrophora is a large leathery lichen, dark greenish brown above with a black felt-like mass of rhizoids beneath. The plant is attached to the rock substrate by a short tough umbilicus. Umbilicaria is a smaller thinner lichen than gyrophora, light brown in color with wart-like pustules above and no rhizoids beneath. The plant is also fastened to the substrate by a short umbilicus.

[1]Papers from the Department of Botany, The Ohio State University, No. 460.

Experimental data concerning the water relations of lichens are not numerous and are of limited pertinence to our problem. It has been recognized that most lichens do not normally contain much water, that some specimens when moistened attain fresh weights three to four times their dry weights, and that probably some species living in desert and other arid habitats are dependent on the atmosphere and dew for available water. Smith (1921), in a review of the literature to that time, reports that lichens can endure almost complete desiccation during long drought periods. They absorb water over their entire surface and water may be held for some time by rhizoids and gradually absorbed. Heugebauer (1939) studied the water relations of several species of *Parmelia* and of *Usnea dasypoga* and reported differences in rates of water loss and in total amount of water held. Lundegardh (1931) suggests that on naked rock surfaces only small slowly growing plants such as algae and lichens can withstand the periodic desiccation. Weaver and Clements (1938) assert that lichens flourish during periods of wet weather and remain in a state of desiccation for very long periods during drought.

MATERIALS AND METHODS

Samples of lichens were collected in the field, placed in glass bottles with plastic screw-caps, and transported as soon as possible to the laboratory for fresh weight and 103° C. oven-dry weight determinations. Water content is expressed as per cent of the oven-dry weight. It was recognized that some non-uniformity in water content among plants in the same general habitat would probably exist and care was taken to reduce this sampling error by taking large samples consisting of small pieces from many plants. Statements about the water content of intact plants at any particular time are based on samples taken at that stated time. Humidity determinations were made with a Friez aspirating psychrometer. Temperature measurements were made with a Leeds and Northrup portable potentiometer and copper-constantan thermocouples inserted into the lichens or exposed to the air.

FIELD EXPERIMENTS

The first experiment consisted of taking samples of both plants at intervals for a twenty-four hour period. The data are shown in Table I.

TABLE I

Data of June 28–29, 1941

Solar Time	Per Cent Water		Temp. in °C.	
	Umbilicaria	Gyrophora	Air	Lichen
1:30 P. M.	18.7	18.6	34.4	32.5
3:30 P. M.*	123.1	365.0	27.2	33.2
5:30 P. M.	37.9	50.1	28.2	32.5
5:30 A. M.	56.9	53.3	22.8	25.5
9:30 A. M.	58.3	44.9	28.6	30.0
11:30 A. M.	28.2	17.9	31.4	38.0
1:30 P. M.	24.0	13.6	28.3	32.0

*Thunder-showers of 0.2 in. between 2:10 P. M. and 2:50 P. M.

The high water content of the samples following the forty minutes of thunder-showers and the rapidity with which much of the water was lost as evidenced by the succeeding samples should be noted. Later laboratory work showed that the water content of gyrophora plants in equilibrium with a saturated atmosphere at

30° C. was 92 per cent. Hence much of the water in the gyrophora plants at 365 per cent water content must have been loosely held on the plant surfaces, not absorbed internally, and evaporated rapidly from the plants. The rhizoids of gyrophora would hold much more water on the surface of the plant than would be held in umbilicaria.

For comparison with Table I, data obtained at a later date are presented in Table II. No rain had fallen in the valley for several days prior to the date of collection.

TABLE II

Data of July 5-6, 1941

Solar Time	Per Cent Water		Vapor Pressure	Temp in °C.	
	Umbilicaria	Gyrophora		Air	Lichen
4:30 A. M.	112.3	85.4	12.5	18.3	20.0
10:30 A. M.	44.6	46.3	17.5	23.9	25.0
1:30 P. M.	25.3	25.3	17.5	25.8	28.5
4:30 P. M.	16.3	17.4	18.5	28.3	36.5
4:30 A. M.	100.4	74.3	15.5	19.4	24.0
7:30 A. M.*	113.2	82.1	16.5	19.7	23.0

*Light rain falling.

The evidence of considerable increase in water content in the absence of rain during the night hours should be noted. In all other experiments performed which included samples taken at night, evidence of increase in water content during the night was obtained. These findings indicate that extreme drought periods during the summer in this region are limited for these plants to some of the daylight hours. Results of several nights collections at one hour intervals showed no regularity in the rate of water absorption and no uniformity in the amount of water absorbed from night to night.

In an effort to determine whether the water absorbed at night came from the rock substrate or the atmosphere, several experiments were performed with gyrophora plants. Initial samples were taken in the afternoon. At the same time some specimens were detached from the rock, mounted on paraffined papers, and the papers fastened to the rock surface. The next morning, samples were taken of intact and paper mounted plants. Table III summarizes the data. Station A was a more exposed and higher place on the cliff wall than Station B.

TABLE III

Solar Time, Date and Sample	Per Cent Water, Gyrophora	
	Station A	Station B
2:30 P. M. June 25, 1942, initial sample	22.0	.....
4:50 P. M. June 25, 1942, initial sample	.....	25.0
4:30 A. M. June 26, 1942, final samples—intact	34.0	39.0
paraffined paper	42.0	35.0
4:30 P. M. August 15, 1942, initial samples	17.0	21.0
4:45 A. M. August 16, 1942, final samples—intact	27.0	30.0
paraffined paper	32.0	37.0

Humidity and temperature measurements during the course of the experiments showed that no dew point temperatures were reached at the plant surface or in the air adjacent. No other visual evidence of dew was noted at points that high above the valley bottom. Since both intact and detached plants mounted on paraffined papers absorbed water overnight in fairly comparable amounts it seems likely that the increase in water content during the night hours was due to the imbibition of water vapor into the plants.

The data of Tables I and II indicate a reduction in water content of these lichens during the daylight hours. Visual and physical evidences of this fact have been experienced by the writers in the field many times. Both plants commonly become brittle and gyrophora curls so that the lower surface is exposed (Fig. 1). More detailed data from an experiment with gyrophora plants that were collected from a tree-shaded habitat dominated almost entirely by this species are presented in Table IV. In Table V are similar data for umbilicaria plants collected

TABLE IV

Data of July 22, 1941

Solar Time	Per Cent Water Gyrophora	Vapor Pressure	Temp in ° C.	
			Air	Lichen
4:30 A. M.	33.9	11.5	15.6	22.5
5:30 A. M.	26.0	11.5	15.6	23.0
6:30 A. M.	33.2	11.5	15.6	22.5
7:30 A. M.	31.8	13.0	17.5	22.0
8:30 A. M.	28.9	15.0	20.3	24.5
9:30 A. M.	29.6	14.5	20.6	25.5
10:30 A. M.	18.9	17.5	23.9	28.0
11:30 A. M.	17.5	16.0	24.4	28.0
12:30 P. M.	18.6	15.5	25.0	28.5
1:30 P. M.	18.2	16.0	26.1	28.0
2:30 P. M.	17.0	15.5	25.3	28.5
3:30 P. M.	16.1	16.5	24.7	27.5
4:30 P. M.	17.6	17.5	23.6	27.5

from a cliff top station somewhat shaded by a pine tree. These latter plants were collected on what proved to be the hottest day in three summers. Table VI is included to show the water content of umbilicaria plants fully exposed to solar radiation during the warmest part of that day.

The water content of both lichens decreased during the morning and early afternoon hours due to the diffusion of water vapor from the plants. Calculations of the adjacent atmospheric vapor pressures from psychometric data show a small increase in atmospheric vapor pressure during those hours. The vapor pressure of water in the lichens, then, must have been increasing to an even greater extent than that of the atmosphere or transpiration could not have occurred during those hours. However, as the water content of the plants decreased, the degree of hydration of the plant material should decrease and the vapor pressure decrease to a point approaching that of the atmosphere. One must account for an increase in vapor pressure of the water in lichens whose water content is decreasing. The temperature data show that the temperature of the lichens was commonly higher than that of the air adjacent; this fact would seem to bear a casual relationship to extended periods of water loss from the plants. The data of Table V and Table VI indicate that the more exposed the plants to direct solar radiation, the higher

the plant temperature and the lower the water content. In all of the field work in which samples were taken from several regions of the cliff wall at the same time, the lowest water contents were found in the plants exposed to direct solar radiation. The high plant temperatures existing under such conditions would account at least in part for high plant vapor pressures and steeper vapor pressure gradients between plant and atmosphere, and hence for lower water contents.

TABLE V

DATA OF JULY 26, 1941

SOLAR TIME	PER CENT WATER UMBILICARIA	VAPOR PRESSURE	TEMP. IN °C.	
			Air	Lichen
4:30 A. M.	24.8	16.5	21.7	25.5
5:30 A. M.	29.0	18.0	22.2	27.0
6:30 A. M.	20.6	18.0	22.8	27.0
7:30 A. M.	22.5	18.5	25.0	27.0
8:30 A. M.	18.7	20.5	27.2	30.5
9:30 A. M.	18.1	21.5	29.4	34.0
10:30 A. M.	16.4	23.5	30.0	39.0
11:30 A. M.	12.7	22.0	28.9	39.5
12:30 P. M.	13.0	23.0	30.6	42.5
1:30 P. M.	11.3	23.5	35.0	42.5
2:30 P. M.	11.4	.....	35.6	38.5
3:30 P. M.	10.7	.....	35.3	36.5
4:30 P. M.	10.6	24.5	32.8	33.5

TABLE VI

DATA OF JULY 26, 1941

SOLAR TIME	PER CENT WATER UMBILICARIA	VAPOR PRESSURE	TEMP. IN ° C.	
			Air	Lichen
12:30 P. M.	8.4	.....	43.5	45.0
1:30 P. M.	6.5	.....	40.0	48.5
2:30 P. M.	6.4	.....	43.0	50.5
4:30 P. M.	7.8	.....	39.0	44.0

DISCUSSION

Evidence of marked diurnal fluctuations in water content of these lichens has been presented. Precipitation water or condensation water may be imbibed by these plants and even held by capillarity. The data show, however, that water absorption of some magnitude may occur between periods of precipitation or condensation. The writers' opinion that the direction and rate of water vapor diffusion will explain fluctuations between rains is supported by the experimental results. The factors of greatest importance in determining the direction and magnitude of vapor pressure gradients between these plants and the atmosphere are temperature differences between plants and atmosphere, and changes in the degree of hydration of the plant tissue as they may affect the vapor pressure of water in the plants.

If an imbibition-transpiration mechanism of the water relations of these lichens is valid, it should be possible to predict changes in water content under controlled conditions. Atmospheres of known vapor pressure may be obtained over sulphuric acid solutions of known density and temperature. Lichens with vapor pressures higher than that of a given atmosphere should lose water to that atmosphere until an equilibrium is established. Lichens with vapor pressures lower than that of a given atmosphere should imbibe water vapor until an equilibrium is established.

Gyrophora plants were brought from the field into the laboratory and samples suspended over sulphuric acid solutions of varying density at constant temperature. By using a large ratio of sulphuric acid solution to plant material and air space, the changes in density of the acid due to loss or gain of water were small. The relationship between the equilibrium vapor pressures and the water contents of the lichen

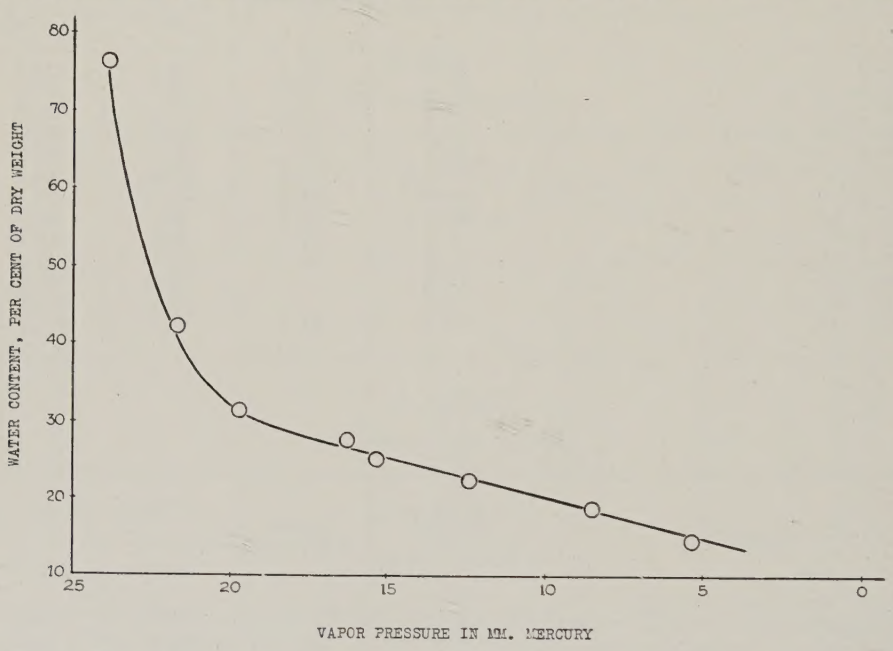

FIG. 2. The water content of samples of *Gyrophora* in equilibrium with sulphuric acid solutions of known vapor pressure at 24° C.

samples is shown in Figure 2. The curved line would represent the path of change in water content of a given sample of gyrophora plants in equilibrium with a saturated atmosphere as it came into equilibrium with sulphuric acid solutions of increasing density and decreasing vapor pressure. The shape of the curve indicates that water above 30% water content is held very loosely and small changes in the equilibrium vapor pressure result in large changes in the percentage water content. At water contents below 30% in this experiment, the water is held more tightly and large changes in the equilibrium vapor pressure result in relatively small changes in the percentage water content.

The results of the experiment substantiate the idea of imbibition of water vapor by these plants and transpiration from them. Attempts to utilize this method to estimate the actual vapor pressures of water in plants in the field by finding the vapor pressure at which no change in weight of the sample occurred, met with technical difficulties. Obviously the temperature of the plants at the

time of collection would have to be known and kept constant in order to keep the vapor pressure constant. The temperature of the sulphuric acid solutions would have to be carefully regulated to that of the plants in the atmosphere above. Errors due to uncontrollable variations in these last mentioned factors were too great to make the method useful in the field.

A laboratory experiment was performed to test the influence of solar radiation on the rate of water loss from water saturated plants on the final equilibrium water content. Gyrophora plants were soaked in water for several hours and then suspended in air until water ceased to drip from them. They were spread out on a laboratory table and their fresh weights determined at regular intervals until they reached constant weight. The oven dry weight of the plants was then determined and the fresh weights converted to per cent of water on a dry weight basis. A similar experiment was performed with gyrophora plants spread out

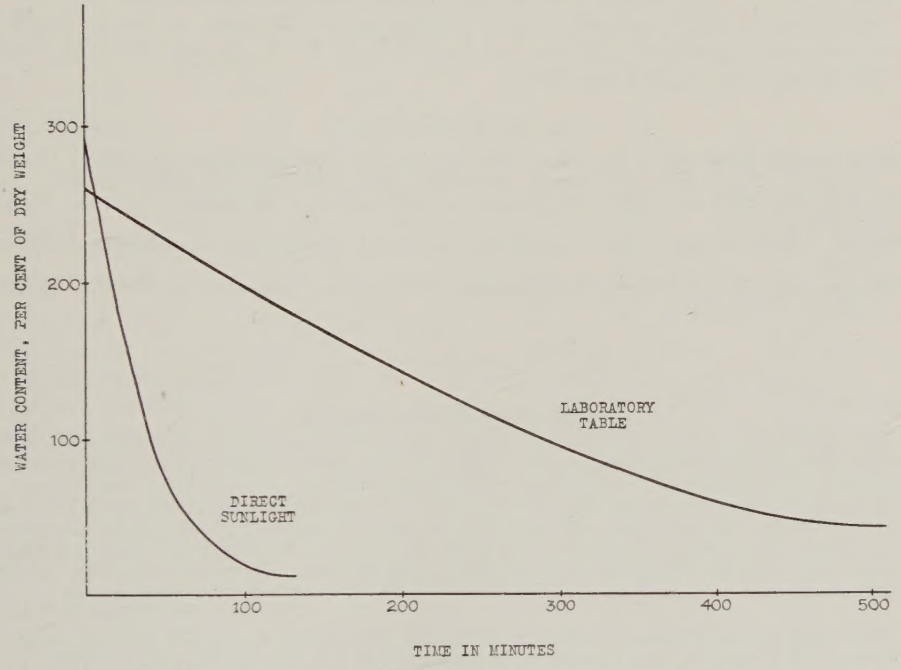

FIG. 3. Drying curves of *Gyrophora* samples indoors on a laboratory table and out-of-doors in direct sunlight.

on a glass plate on the ground outside the laboratory and exposed to solar radiation. The data are presented as drying curves in Figure 3. The slope of the curves indicates relative rates of water loss and the final equilibrium water contents are apparent as the curves flatten out parallel to the abscissa. The influence of solar radiation is apparent on inspection and in agreement with field data.

SUMMARY

Field experiments were performed with two species of lichens growing on the southwest facing cliff walls of a valley in Hocking County, Ohio. Data on the percentage water content on a dry weight basis, plant and air temperatures, and atmospheric humidity were obtained at various intervals during two summers.

The results of these experiments indicate that these plants do not remain in a state of desiccation during periods between rains or dew, but exhibit a marked

diurnal fluctuation in water content. During the daylight hours, particularly in clear weather, the water content decreases due to transpiration. Extended periods of transpiration are possible because the temperature of the plants was found to be commonly higher than that of the air adjacent, especially if exposed to solar radiation. Such temperature differences would cause the occurrence of a vapor pressure gradient from plants to atmosphere even at low water contents of the plants. During the night hours, imbibition of water vapor into the lichens occurs whenever the vapor pressure gradient is from atmosphere to plants. Such a condition may exist when plants at low water content become cooled at night to a temperature close to that of the atmosphere.

Laboratory experiments were performed and the results substantiate the fact that these lichens may gain water vapor by imbibition and lose water vapor by transpiration. The effect of solar radiation on increasing the rate of transpiration and lowering the final equilibrium water content was also demonstrated.

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LITERATURE CITED

1. **Heugebauer, Hans F.** 1938. Zur Ökologie von in Buchenkronen eiphytisch lebenden Flechten. Beitr. Biol. Pflanzen 25: 273–289. (Biol. Abst. 13: No. 3504. 1939.)
2. **Lundegardh, Henrik.** 1931. Environment and plant development. p. 163. Edward Arnold & Co.
3. **Smith, Lorrain Anne.** 1921. Cambridge Botanical Handbooks. Cambridge University Press.
4. **Weaver, John E. and Frederic E. Clements.** 1938. Plant Ecology. pp. 66–68. McGraw-Hill Book Co., Inc.

Monograph on Florida Crayfishes

This publication has grown out of ten years work on Florida crayfishes by Horton H. Hobbs, Jr. The data presented are based upon a collection of over ten thousand specimens collected by himself and colleagues of the University of Florida.

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—*Wilbur M. Tidd.*

The Crayfishes of Florida, by Horton H. Hobbs, Jr. Pages v and 179, 24 full plates and 346 figures. Published by the University of Florida, Vol. III, No. 2, November, 1942. Paper bound. Price $2.25 plus postage.

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